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Using Reflective Practice to Facilitate Conversations and Transform Instructional Practice for Middle School Science Teachers

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USING REFLECTIVE PRACTICE TO FACILITATE CONVERSATIONS AND TRANSFORM INSTRUCTIONAL PRACTICE FOR MIDDLE SCHOOL SCIENCE TEACHERS

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ABSTRACT

The process of teaching, especially inquiry, is complex and requires extended time for developing one's instructional practice (Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2010). The implementation of a continued cycle of self-reflection can engage teachers in analyzing their prior experiences and understandings about their instructional practice to promote the accommodation of new concepts and transform their practice. However, many teachers have difficulty engaging in the cognitive dissonance needed to identify those problems and promote their own growth without support. As one's professional practice becomes more repetitive and routine, it is difficult for the practitioner to recognize opportunities in which to contemplate one's habitual actions (Schon, 1983).

In this multi-case study, two middle school science teachers who were engaged within a sustained professional development initiative participated in a series of one-on-one reflective dialogues regarding the decisions they made about the utilization of inquiry-based instruction. In addition, these teachers were asked to reflect upon the criteria used to determine how and when to implement these inquiry-based practices. These reflective dialogue sessions provided the opportunity to observe teacher conceptions and stimulate teacher cognitive dissonance about instructional practice. Qualitative analysis of data collected from these reflective dialogues along with informal and formal classroom observations of instructional practice uncovered diverse perceptions regarding the implementation of inquiry-based methods into present teaching practice. The use of reflective dialogue within the existing structure of the professional

development initiative allowed for the facilitators of the professional development initiative to tailor ongoing support and their effective implementation of inquiry-based instruction. Additional research is needed to investigate the impact of reflective dialogue in achieving accommodation of new concepts leading to lasting conceptual change about inquiry-based instruction.

DEDICATION

The findings and implications of this study are dedicated to all science educators who are seeking to meet the challenges of implementing inquiry-based instruction. By embracing the philosophy of "explore before explain" and seeking to become a "teacher as facilitator," you are giving your students the tools to become productive citizens and problem solvers in the 21st century.

This successful completion of this process in pursuing my doctorate would not have been possible without the unconditional love and support of my family and friends. They offered quiet encouragement during both the productive and dormant times and always assured me I could accomplish this goal. You have been my rock during this intellectually and emotionally challenging journey.

Finally, I owe an enormous amount of thanks and appreciation to my parents, the late Earl Higdon, Jr. and Gail Higdon. They taught me the value of education and the importance of always doing your best, even when you think no one notices. They always assured me the sky was the limit as long as I had a plan to get there. Most importantly, I want to express my enormous gratitude to my mother. She willingly took every step of this journey along side of me; sometimes gently pushing me along, and sometimes pulling me over the hurdles. She is my inspiration for everything I do and I love her very, very much.

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CHAPTER ONE

INTRODUCTION

With the rapid advances in science and technology in the 21st century, today's students in K-12 classrooms will be challenged to interact with an ever-changing, complex world. The amount of information and knowledge available to students is growing more rapidly now than at any other time in history, and increasing one's knowledge of learning theory can translate to continuous improvement of one's instructional practice (Bransford, Brown, & Cocking, 1999; Linn, Elyon, Rafferty, & Vitale, 2015; Sinatra et al., 2014). According to Gallagher and Stepien (1995), "an understanding of science is increasingly critical to effective functioning in a democratic society, as issues including nuclear power, balancing industry and the environment, and increasingly complex health care technologies become a part of everyday life" (p. 136).

As employees in this modern, global workplace, students within these 21st century classrooms will need technical skills as well as problem finding and solving skills. Countries that provide and distribute opportunities for all students to gain these skills in critical thinking and problem solving will likely be more competitive within a global society (Lewis, 2007; Michaels, Shouse, & Schweingruber, 2008; National Academies Press, 2010; NGSS Lead States, 2013). Students who have engaged in learning science through an inquiry-based approach have become more scientifically literate and are able to make personally relevant decisions (Sinatra, Kienhues, & Hofer, 2014). When students become active participants in their learning, they gain a deeper understanding of and demonstrate higher levels of mastery which, in turn, will ultimately enable them to apply

these skills to their lives as active members of a global workforce and a complex, ever-changing 21st century society (NGSS, 2013). However, in recent years, the United States' ability to compete for jobs within a global economy has trended in a flat or negative direction (OCED, 2013).

Calls for reforms in science education have been a priority since the release of *A Nation at Risk* in the early 1980s. This report from the National Commission on Excellence in Education (1983) expressed concerns about the state of public education in general as well as the lack of students entering science-related fields. Since that time, several documents have been produced outlining a vision for science education such as Project 2061 Benchmarks for Science Literacy (AAAS, 1993) and the National Science Education Standards (National Research Council, 1996). The study and adoption of these frameworks and standards propelled the recent publication of *The Next Generation Science Standards: For States, By States*. This current version of national science standards "represent[s] a fundamental change in the way science is taught and, if implemented well, will ensure that all students gain mastery over core concepts of science that are foundational to improving their scientific capacity" (p. 1, National Academies Press, 2015).

However, with the development of the Next Generation Science Standards (NGSS), there may be a considerable gap "between the reality of current teaching practices and the vision of science learning" (p. 12, National Academies Press, 2015). For many science teachers, implementing this constructivist approach will require accommodating new conceptions about teaching science. Teachers will be challenged to

shift from utilizing traditional teacher-centered methods to becoming facilitators of learning within their classrooms. This shift will require science educators to expand their knowledge and enhance their practice; a transformation which will push many educators out of their current comfort zone. Therefore, educators engaged in professional development initiatives will need considerable support in order to accommodate a shift in their held conceptions about inquiry-based instruction and normative classroom practices.

Rationale

As practitioners, educators become very adept at implementing their instructional methods without much cognitive demand. Therefore, they often continue to utilize practices that are ineffective or unsuccessful without being able to assess the effectiveness of those practices (Downey, Steffy, English, Frase, & Poston, Jr., 2004; Schon, 1983). Existing ideas and beliefs can constrain new knowledge acquisition. Exposure to new information is not the same as understanding or assimilating that information into currently held conceptions. Engaging in continuous learning throughout one's career promotes effective teaching and learning (Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2010). As learners, teachers may only consider changing their held conceptions when a new concept or strategy shows measurable achievement or behavioral change (Eylon & Linn, 1988; Marshall & Horton, 2010; Schön, 1983; Vosniadou, 1996; Vosniadou & Skopeliti, 2014). Therefore, implementing any form of instructional practice can involve an intricate sequence of planning, acting, observing, and reflecting as well as continually making decisions about classroom interactions that are constantly changing.

The first step in transforming one's practice is to recognize there is a problem in current practice (Marshall & Horton, 2009). Engaging in models of reflective practice can serve as a vehicle through which teachers can enhance skills and address ineffective practices (Rebore, 2012). Leithwood (as cited in Levin, 2008) stated that having opportunities to learn and improve skills and having a strong collegial environment that encourages dialogue among peers were major contributors to teachers' satisfaction with their work environment. Using reflective practice models such as engaging teachers in one-on-one dialogues to facilitate an analysis of instructional practices can enable them to question their practice within a current, established comfort zone established through repeated, interactive experiences to make meaning of their identified conceptions (Downey et al., 2004). The goal is not to directly change teacher behavior but to influence teacher conceptions resulting in the teacher's recognition and acceptance of those currently held conceptions in order to change one's behaviors.

Discussions of gaps between verbalized understanding of conceptual knowledge and observed instructional practice are ripe for study within the context of designing and implementing effective professional development. During professional development initiatives, some practitioners may resist adopting specific instructional dispositions in aggressive and transparent ways. Other practitioners appear to fully adopt the new dispositions yet their observed practice indicates a variance between stated understanding and conceptual understanding. These educators need to be provided ways for the identification and acceptance of their inconsistencies in theory and practice in order to fully accommodate new conceptual knowledge.

Research Questions

This study emerged from a pilot study that utilized an exploratory case study design (Yin, 2009) in which six science teachers from the same middle school involved with a sustained professional development initiative were observed and interviewed multiple times during their first two years of participation. This initiative met the criteria for effective professional development in terms of being sustained, embedded, and supported within each teacher's instructional context (Capps, Crawford, & Constas, 2012; Guskey, 2003). Teachers who were able to fully conceptualize inquiry-based instructional methods using the model presented within the professional development initiative should have experienced a sustained transformation in practice. An analysis of the data from all participants within the initiative the two years prior to this study indicated that many of the teachers showed sustained improvement (Marshall & Alston, 2014). However, it was observed that two teachers from this cohort of participants displayed unique characteristics, in that they were making inconsistent progress in their implementation of inquiry-based methods as learned during the professional development meetings as compared with the other teacher participants. Although these two teachers consistently expressed strongly held beliefs about the use and implementation of inquiry-based methods that aligned with the conceptual model presented within the professional development initiative, their observed instructional practice was inconsistent with these beliefs.

Therefore, the following research questions were developed:

> 1) How do science teachers describe their conceptions of inquiry-based practice during reflective dialogue?

2) How are these expressed conceptions about inquiry-based practice represented in their instructional decision making process?

3) Can engaging in reflective dialogue bring about conceptual change regarding inquiry-based practice?

Structure of the Study

This study seeks to examine the use of a reflective practice model and its impact on stimulating cognitive dissonance to advance conceptual understanding about the use of inquiry-based methods. As participants engage in reflecting upon their decision-making processes, their responses may uncover any factors that could be contributing to resistance in transforming practice. These identified factors will then serve as a basis for questions posed to participants in subsequent sessions of reflective practice in order to continually engage them in a cycle of analyzing their held conceptions and how those understandings impact their implementation of the inquiry-based models presented through the professional development initiative.

This dissertation is organized traditionally using a five chapter format. Chapter two, which follows this introductory chapter, contains a review of the literature. Chapter three outlines the context in which this study took place and the design structure of this multi-case study. Profiles of the two teachers who participated in the study are also contained in chapter three. Chapter four presents the findings for each of the participants taken from the data collected during the study. Chapter five contains discussion and summary of the findings as well as connections to future research questions.

Significance

Being able to uncover the reasons why some educators are not able to fully implement these reforms within their practice can assist professional development providers in their work. With the introduction of any new initiative, there are participants who do not respond to the standard professional development practices. As the learning process for each person is unique and complex, every participant responds differently to the elements of a professional development initiative. Within this study, a reflective practice model was added in order to uncover held conceptions that could be influencing one's implementation of inquiry-based practice. The use of a reflective practice model can move teachers beyond their comfort zone and initiate a process by which they can question their decision making processes within a safe, supported environment (Downey et al., 2004). In turn, future professional development activities for teachers can efficiently utilize resources, sustain transformations in practice, and enhance the profession.

In addition, effective professional development providers should seek ways in which to facilitate sustained transformations for all participants, including those who exhibit unique characteristics or who respond to the interventions in ways that do not align with the majority of the learners. This study aims to discern ways in which identified outliers within a population of participants can be assisted in accepting the reform message in order to promote sustained transformations in practice. The use of a reflective practice model can enable professional development providers to detect held conceptions about inquiry-based instruction as well as potential gaps within the design of

the professional development with the goal of making the initiative replicable for all learners.

Limitations

The case study method can be perceived as having a rack of precision, and thereby, a lack or rigor. The use of a case study method has often been faulted because it lacks generalizability and representativeness since the findings are limited to the experiences of one case (Merriam, 2009; Yin, 2009). However, the use of this particular method can allow the researcher to carry out the investigation of the specific case within the natural setting as decoding the influence of the context is of equal importance as the decoding of participant responses (Lincoln & Guba, 1985). This, in turn, does allow for a rich and robust interpretation of observed phenomena.

As this study took place within a naturalistic setting and utilized an emergent design, the findings can only be used to generate hypotheses and research questions that can be investigated using qualitative methods (Lincoln & Guba, 1985). The research design of this study organically evolved from responses which emerged from each successive reflective dialogue as it would have been unfeasible to predict in advance the interactions between the participants and researcher in order to design and implement rigid protocols (Lincoln & Guba, 1985). The exact research plan cannot be replicated by another researcher as the design and, therefore, the findings were very specific to context and participants.

Limitations attributed to the researcher

The researcher had a sustained period of involvement within the professional development initiative. Within the context of this study, the researcher served in the roles of both the instrument of data collection and analysis and the provider of professional development. Having such close ties to the study participants can be a strength as the researcher had a deep understanding of the context of the study and adequate training to use the protocol. On the other hand, having the researcher in dual roles makes it difficult to verify findings. The interpretation of results can be clouded by having an in-depth, insider understanding of the situation and can confound the validity of the study. These perceived biases could factor into decisions made about data collection and analysis and provide solutions that are researcher-dependent. In future, data analysis and coding procedures should be triangulated among researchers rather than being limited to the analysis to the data performed solely by the researcher.

The teachers chosen for involvement within this study were purposefully selected from a single cohort within the professional development initiative. This study was purposefully limited to these participants in order to optimize results within the constraints of the school day and instructional time. Using this approach allowed the researcher to investigate and analyze a complex phenomenon into small, useable, doable pieces. In addition, this approach provided an opportunity to examine real-life situations rather than utilizing simulations of these environments. The study could go deep into the context to understand the participant's point of view and provide multiple opportunities to verify understanding. The selection of two participants did allow for the collection of

rich data that can be used to develop a robust understanding of each participant's conceptions of inquiry-based instruction.

Limitations attributed to the method

Within the use of case study methods, the end of the study usually occurs when saturation occurs. However, this study had a pre-determined termination point as situational factors determined the end of the data collection phrase rather than allowing the data collection to be directed by obtaining saturation. For example, the study could not continue beyond the conclusion of the school year, and the participants were not returning to the same classroom context in which they were placed during the context of the study. In addition, these situational factors did not allow the researcher to control for unplanned events; therefore, the findings are shaped by extraneous factors and lose external validity.

Definitions of Key Terms

Inquiry-based practice: instructional methods that involve students working through a process of identifying a question, developing and testing a hypothesis, collecting and analyzing data, and formulating conclusions based upon the results. Inquiry-based practice spans a continuum of varied roles for both teacher and student from being very prescriptive to fully open-ended (Marshall, 2013).

Reflective practice: the systematic evaluation and reflection of one's practice in which the practitioner identifies aspects of experiences and builds new understandings of those experiences to inform the decision making process within the current context (Schon,

1983). For this study, reflective practice is implemented and examined within the context of implementing inquiry-based methods within the classroom.

Reflective dialogue: one-on-one conversation facilitated by the researcher with a single study participant. This conversation begins with a purposefully worded question to engage the teacher in a thoughtful examination of the decision-making process utilized within the implementation of inquiry-based practice. In this study, these dialogues were used to motivate the participant into questioning her practice by creating a sense of cognitive dissonance in order for the teacher to "question their behavior, reflect about practice, seek out new knowledge, and change their practice so that more children are learning at high levels" (Downey et al., 2004, p. 136).

Conceptual change: learning that occurs when individuals manufacture a major reorganization in their thinking about some idea, concept, or theory. This model outlines the process by which a learner gradually assimilates a new conception after the identification of and willingness to change held conceptions. Within this process, a learner's prior knowledge must be accessed, identified, and evaluated for misconceptions. Conceptual change then occurs when the learner fully accommodates the new conception in place of the previous held understanding (Posner, Strike, Hewson, & Gertzog, 1982).

CHAPTER TWO

LITERATURE REVIEW

In support of this study, findings from the literature regarding a rationale for the utilization of inquiry-based methods along with some identified challenges for implementation of those methods will be presented. Next, the theoretical framework for the study, the Conceptual Change Model (CCM) will be outlined. Then, findings from the literature regarding the role of the Conceptual Change Model, the Cognitive-Affective Model of Conceptual Change (CAMCC), and reflective practice in promoting changes within instructional practice will be discussed. Then, the specific tool chosen for this study, one-on-one reflective dialogue, will be presented along with the rationale for how this specific intervention supports facilitating transformations in practice. Finally, the design and role of professional development in facilitating teachers' abilities to accommodate newly held conceptions regarding their practice will be examined.

Rationale for Use of Inquiry-based Methods within the Science Classroom

For many years, science educators have recognized the importance of providing students with opportunities to actively explore the world around them in order to encourage students to examine held concepts about natural phenomena. As stated in *A Framework for K-12 Science Education*:

> In order for students to develop a sustained attraction to science and for them to appreciate the many ways in which it is pertinent to their daily lives, classroom learning experiences in science need to connect with their own interests and experiences (National Research Council, 2012, p. 28).

Inquiry-based instructional methods can provide such a meaningful approach in developing this awareness of scientific concepts as students are "doing" rather than just "seeing" the science to cultivate their own meanings to scientific concepts and principles (Jorgenson, Cleveland, & Vandosdall, 2004). Enabling students to become more proficient in generating and testing hypotheses builds needed skills to question the forces and events in the world around them beyond the classroom setting.

As students move into society as productive citizens, whether in a science-related field or not, their decisions should be based on scientific research (Sinatra et al., 2014). Therefore, students need to see scientific practice in a broader sense of being able to construct knowledge claims about the natural world and to defend those claims in a community of critical minds. The National Science Teachers Association (2004) recommends that teachers at all grade levels actively embrace scientific inquiry within their instruction to assist students in developing a deep understanding of scientific concepts and processes needed to develop understandings about the world around them. The *National Science Education Standards (NSES)* gives the following definition of inquiry:

> Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities through which students develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world (National Research Council, 1996, p. 23).

The *Next Generation Science Standards* builds upon these recommendations by stating:

> An essential part of science education is learning science and engineering practices and developing knowledge of the concepts that are foundational to science disciplines. Further, students should develop an understanding of the enterprise of science as a whole—the wondering, investigating, questioning, data collecting and analyzing (NGSS Lead States, 2013, Appendix H, pg. 1).

Instructional practices that emphasize the memorization of facts, are textbook-driven, and utilize assessments designed to evaluate a student's ability to recall those facts can hinder a student's development of scientific concepts. This practice encourages students to produce acceptable answers without necessarily having the conceptual understanding to explain why that answer is correct (Hutchinson & Hammer, 2009; Manz, 2015). For students to develop competency within the scientific discipline, they must have occasions to learn with understanding in order to transform factual knowledge into usable knowledge (Bransford et al., 1999). As it is an innate process to question what one experiences within the natural world, learning the scientific concepts should mimic this process. Inquiry-based methods also parallel the way we, as humans, learn by putting the attainment of knowledge and skills in the hands of the learner rather than the instructor (Jorgenson et al., 2004).

Research findings in science education suggest that effective learning environments should foster active student engagement and give students opportunities to construct their own knowledge and skills (Hutchinson & Hammer, 2009; Manz, 2015; Marshall, 2013). In order to better design these effective environments for teaching science, educators need to understand how children learn science and how specific

science concepts are acquired (Manz, 2015; Vosniadou, Ioannides, Dimitrakopoulou, & Papademetriou, 2001). Odom and Kelly (2001) write that students need multiple experiences with the inquiry process in order for them to become more proficient with constructing knowledge claims about the world around them. The more proficient students become in generating and testing hypotheses, the more likely they are to improve their procedural knowledge which in turns influences a student's ability to generate declarative knowledge. As students may be able to generate more meaningful declarative knowledge, the better they may be able to understand the forces and events in the world around them. For students to gain this understanding, O'Neill and Polman (2004) suggest for mandated curricula to include less content and give students more opportunities to build deeper understandings of how scientific theories are constructed through practice-based science literacy. This approach can also stimulate interest in learning for students whom traditional lecture and seatwork are especially ineffective (Jorgenson et al., 2004) by actively engaging those students. Middle-level learners are naturally inquisitive and inquiry-based methods embrace their intrinsic tendencies (Jorgenson et al., 2004) while providing a structured support system in which to explore new learning and present their own interpretations of the evidence gathered through experimentation and research.

To stimulate student interest in "doing" the science, teachers must design their science instruction to look and feel like science as it is conducted in the real world and workplace. Fact-filled textbooks and cookbook-style lab activities do not promote the level of critical thinking needed to produce conceptual change. In order for meaningful

learning to take place, science educators must provide inquiry-based learning experiences that allow students to explore these preconceptions and compare them to recognized understandings of scientific phenomena. (Gallagher & Stepien, 1995; Limon, 2001; Manz, 2015; O'Neill & Polman, 2004). Hutchinson and Hammer (2009) stated:

> Learning science means, in part, making progress toward understanding concepts and phenomena as scientists understand them. It should also mean making progress toward understanding intellectual activities as scientists do. We take it as an essential instructional goal that students come to understand inquiry in science as making sense of natural phenomena… (p. 510).

Asking students to "do" more science can be a frustrating experience, especially as students first experience this type of learning environment. In Wolf and Fraser's (2008) study of using inquiry-based lab activities with middle school students, they found that students struggled at first being asked to design appropriately-controlled experiments in an inquiry-based classroom setting. However, as the students became familiarized with the process, they required less prompting from their teachers. The students in the inquiry-based group explored a wider range of materials which led to more in-depth class discussions. These students demonstrated a greater gain of content knowledge not evident in the non-inquiry classes. Overall, the students in the inquiry class appeared to gain some benefits from an inquiry-based instructional approach although there was not a statistically significant difference in overall academic achievement between the two groups (Wolf & Fraser, 2008). In addition, the use of inquiry-based instruction can

engage students from all populations and has a positive, significant impact upon student achievement (Capps et al., 2012; Marshall & Horton, 2010).

Challenges to Implementing Inquiry-based Methods

In their examination of the history of science education reforms within the United States, Abd-El-Khalick et al. (2004) found that when envisioned conceptions of inquiry meet the limitations of schools and classroom instruction, they are often transformed into "insufficient curricula and then translated into incongruent enactments or classroom practices" (p. 398). These inconsistent levels of implementation can be regarded as barriers for the full implementation of inquiry-based methods. Tobin and McRobbie (1996) have identified four major cultural "myths" that secondary teachers have developed about the implementation of inquiry-based methods: the transmission myth, the efficiency myth, the rigor myth, and the exam preparation myth. In the transmission myth, teachers believe that students can only learn scientific concepts if the information is "transmitted" from teacher to student. In the efficiency myth, teachers perceive the coverage of the content is more important than an in-depth study of fewer topics. In the rigor myth, many teachers attempt to add rigor to student learning by assigning more vocabulary terms to memorize or more problems to work. And, with increasing emphasis being placed on passing standardized tests that were part of the No Child Left Behind Act (2001) and are now part of the Every Student Succeeds Act (2015) requirements, teachers may have been more pressured to teach to the test rather than allowing their students time to fully explore concepts, as exemplified by the test preparation myth. The National Education Association (NEA) conducted a phone survey with over 1,500

teachers. The data collected indicated that 72 percent of respondents felt "moderate" or "extreme" pressure from both school and district administrators to improve test scores (2015). According to Wallace and Kang (2004), these myths can permeate the culture of school science instruction, become internalized by teachers, and interfere with the implementation of more student-centered practices. Fletcher and Luft (2011) performed a three-year longitudinal study on evolving teacher beliefs of early career teachers and found that although teachers maintain beliefs about using inquiry-based methods, they typically reverted to more didactic methods upon entering the secondary science classroom. Assisting teachers in identifying and evaluating their currently-held beliefs can better enable them to acknowledge and modify their conceptions about inquiry-based instruction.

Much confusion exists regarding the definition and the different interpretations of what constitutes inquiry-based instruction (Capps et al., 2012; Marshall, Horton, & White, 2009). Throughout their educational and professional experiences, teachers have come into contact with the concept of inquiry in a variety of situations. In each of these situations, the use of the term *inquiry* within these multiple connotations could lead teachers to construct misconceptions and alternate understandings about the meaning of inquiry. For example, science educators can access articles in practitioner journals about inquiry-based lessons that provide a step-by-step instructional plan thereby promoting a conception that inquiry is a set process rather than a conceptual model. Science textbooks also tend to present inquiry-based methods in a linear fashion further contributing to misconceptions about inquiry-based teaching. In their study of six experienced high

school teachers, Wallace and Kang (2004) found that if teachers view the science process as a rigid set of facts or as a linear process rather than practicing science, they tend to be more reluctant to involve students in inquiry-based processes.

Conceptual Change Model

As noted above, *inquiry* is much more than an instructional strategy. Rather the use of inquiry-based methods is a complex process involving multiple components within one's instructional practice (Marshall & Horton, 2010). Therefore, the process of inquiry-based instruction could be viewed as a conceptual model requiring teachers to adopt a new way of thinking rather than implement a strategy. The Conceptual Change Model outlines a framework through which these new conceptions replace currently held conceptions and are accommodated into one's existing schema.

Conceptual change is more than just the addition of new knowledge. Rather, conceptual change is learning that occurs when individuals manufacture a major reorganization in their thinking about some idea, concept, or theory (Posner, Strike, Hewson, & Gertzog, 1982). The Conceptual Change Model (CCM) emerged from research on science teaching, specifically on investigating the role of prior knowledge on student learning. The CCM has its roots in the constructivist view of learning in which learners actively connect acquired knowledge with existing knowledge (Biemans, Deel, & Simons, 2001; Bodner et al., 2001; Limon, 2001; Wade, 1994). According to Bodner, Klobuchar, and Geelan (2001), educators utilize a variety of theoretical frameworks in guiding their decision-making processes. As teachers try to form relationships between familiar practices and new ones, they weave together the dissimilar ideas with their

familiar practices (Cohen, 1990). For significant change to occur, teachers must engage with their prior experiences and understandings about their instructional practice before successfully making accommodations to their practice. The CCM and research on understanding change can provide a framework for understanding how lasting belief change for teachers can take place (Gregoire, 2003).

Stages of the Conceptual Change Model

The elements of the CCM have theoretical roots in the work of Jean Piaget's learning theory about the concept of disequilibrium, the assimilation of new knowledge, and the accommodation of existing knowledge structures to accept new ideas. (Bodner et al., 2001; Collins, 2002; Ozdemir & Clark, 2007; Posner et al., 1982).

Activating prior knowledge. The first key element of the CCM is the identification and awareness of prior knowledge. Vosniadou and Verschaffel (2004) described conceptual change as a method of learning in which new knowledge comes into conflict with currently held conceptions or prior knowledge, which was obtained from common experiences. A concept has to be constructed from the learner's prior knowledge (Posner et al., 1982). Activating prior knowledge can support the construction of rich and useful mental representations with deeper understanding (Biemans et al., 2001). Therefore, for conceptual change to occur, one must undergo a major reassessment and reorganization of one' prior knowledge.

Experiencing cognitive dissonance. To begin a process leading to the construction of new knowledge, a person must first encounter difficulty in using an existing concept or, in other words, an anomaly or dissonance. "An anomaly exists when

one is unable to assimilate something that is presumed assimilable—or (in other words), one simply cannot make sense of something" (Posner et al., 1982, p. 220). This experience creates a source of dissatisfaction with the existing conception, and a person is more willing to consider a new intelligible and initially plausible conception that is available to resolve the dissonance.

Assimilation. As learners are exposed to new concepts to an identified dissonance in their understanding, they begin to evaluate the sufficiency of that new theory. However, if the current conception does not successfully provide a plausible explanation, learners may make only moderate changes or assimilate their conceptions. When presented with new ideas, practitioners attempt to weave together the dissimilar practices with tightly held conceptions. (Cohen, 1990). Concepts begin to develop as individuals assimilate new knowledge within existing ideas and experiences.

Learners tend to directly process new information through assimilation with existing knowledge that is grounded in everyday experiences. Chinn and Brewer (1993) argued that learners tend to engage coping strategies when presented with anomalous knowledge. To better assess the existence of naïve conceptions and resulting conceptual changes, Chan, Burtis, and Bereiter (1997) recognized a dual approach of direct assimilation and knowledge building. This leads learners to assimilate new concepts rather than accommodate them into existing schema. An individual's expectations constructed upon prior knowledge and past experience along with the nature of the perceptual stimuli have a significant impact on these cognitive processes (Vosniadou, 1996). In fact, when new knowledge is assumed without identifying one's prior

knowledge or conceptions, misconceptions can be generated. These misconceptions can then manifest themselves within instructional practice and serve as a barrier to the implementation of these new practices (Vosniadou & Verschaffel, 2004).

Accommodation. After the learner experiences assimilation, the next stage in the model is accommodation (Posner et al., 1982; von Glasersfeld, 1989). Several conditions must be met in order for a learner to accommodate a new conception or replace or reorganize a new theory. The person must first recognize that their existing theory or conception lacks the capacity to explain phenomena and solve problems. Then, the new conception must be intelligible so that the individual can grasp the meaning of an experience. In addition, the new conception must appear plausible in providing understanding to solve problems. Finally, the new conception must appear to be powerful and have the potential for extending one's explorations. Gradual process with each new adjustment in one's existing ideas lays the groundwork for further modifications (Posner et al., 1982).

Constructing knowledge. In addition to the processes outlined by Posner et al. (1982) explaining how knowledge is constructed, von Glasersfeld (1989) argued that the constructed knowledge must be workable for the person to understand similar experiences:

> Knowledge is never acquired passively, because novelty cannot be handled except through assimilation to a cognitive structure the experiencing subject already has. Indeed, the subject does not perceive an experience as novel until it generates a perturbation relative to some

> expected result. Only at that point the experiences may lead to an accommodation and thus to a novel conceptual structure that re-establishes a relative equilibrium. In this context, it is necessary to emphasize that the most frequent source of perturbations for the developing cognitive subject is the interaction with others (p. 136).

Furthermore, von Glasersfeld (1989) proposed that a person's experiences do not occur in isolation; they always include social interaction with others. Learners often begin their study of various concepts with mindsets ranging from having strongly held conceptions, scrutinizing conflicting ideas, or possessing little knowledge, and these personally developed conceptions appear as ways to make sense of their worlds (Bybee, 2002; Linn, Eylon, Rafferty, & Vitale, 2015). Therefore, learners should have opportunities for interactions with others to produce instances of cognitive dissonance leading to conceptual change about their practice.

Changing Conceptions of Instructional Practice

Changing one's knowledge, learning, and teaching involves persons who have a desire, are actively engaged, and have the resources to change (Cohen, 1990). As learners, teachers will only consider changing their ideas if the plausibility of the new concept or strategy is increased more than the existing conception (Eylon & Linn, 1988; Johnson, 2007). Being exposed to new information, however, is not the same as understanding or integrating that information into what one already knows. As one's professional practice becomes more repetitive and routine, it is difficult for the practitioner to recognize opportunities in which to contemplate one's habitual actions.

Challenges to one's practice must be constructed from ideas that are puzzling, troubling, and uncertain (Schon, 1983). Change does not automatically collide with inherited ideas and practices (Cohen, 1990). Individual factors about knowledge acquisition and storage of information must be considered along with the influence of affective and motivational factors and interaction of external factors to examine why it can be difficult for educators to transform held conceptions (Johnson, 2007; Vosniadou, 1996; Vosniadou & Skopeliti, 2014).

Educators continuing to use ineffective practices for longer periods of time usually will not transform their actions into high quality ones as they typically are unable to merge these research-based practices with their instructional practice (Guskey & Yoon, 2009; Schmitt, 2004). When practitioners allow themselves to enter into conflict about their practice, the resulting uncertainty can be perceived as threatening and admission of these doubts seen as a sign of weakness (Schön, 1983). Once an individual reaches an understanding about the lack of validity of their current knowledge, he is more willing to accept new concepts (Vosniadou & Skopeliti, 2014).

Role of the Conceptual Change Model

According to Bodner, Klobuchar, and Geelan (2001), educators utilize a variety of theoretical frameworks in guiding their decision-making processes. As teachers try to form relationships between familiar practices and new ones, they weave together the dissimilar ideas with their familiar practices (Cohen, 1990) echoing the processes outlined in the Conceptual Change Model. The CCM states that a learner must be engaged in cognitive dissonance about held conceptions before being able to

accommodate new conceptions. Individuals are more likely to transform their thinking when they have reason to be frustrated with their existing understanding and can experience cognitive dissonance (Loucks-Horsley et al., 2010; Posner et al., 1982). However, when individuals fail to accommodate new information, it becomes assimilated with prior knowledge. Assimilation can prevent new knowledge from being deeply comprehended. In addition, assimilation of new information requires minimal processing; therefore, it is easier for a learner to assimilate new information rather than fully accommodate (Gregoire, 2003).

Role of the Cognitive-Affective Model of Conceptual Change (CAMCC)

For some practitioners, it can be difficult to engage in the cognitive dissonance needed to identify their prior knowledge and held understandings. For significant change to occur, teachers must be engaged with their prior experiences and understandings about their instructional practice before successfully making accommodations to their practice (Marshall & Horton, 2010; Vosniadou & Skopeliti, 2014). Michele Gregoire (2003) explored various reasons for why teachers struggle to implement subject-matter reforms. She viewed currently held beliefs as possible constraints for the adoption of instructional practices, especially if those beliefs conflicted with a reform message or new beliefs. She developed the Cognitive-Affective Model of Conceptual Change (CAMCC) as a conceptual framework in order to devise a better means of changing teacher beliefs in order to implement new ideas. This approach was designed to address teachers who were positively valuing constructivist-oriented reforms such as inquiry-based methods yet who were not able to implement the methods within their practice. However, these teachers

believed they were sufficiently implementing the reforms within their practice. “The relationship between subject-matter beliefs and practice is a complex one because without significant changes in subject-matter beliefs, maintaining radically new ways of instruction is almost impossible” (Gregoire, 2003, p. 149).

According to Gregoire (2003), the Conceptual Change Model does not take into account the influence of teacher subject matter beliefs or emotional attachments on currently held conceptions. In addition, the CCM does not articulate the mechanisms that lead to lasting conceptual change other than the need to engage the learner in the identification and dissonance regarding currently held conceptions. According to the CAMCC, these beliefs and attachments must be addressed if a teacher is observed struggling to implement a reform-based message, such as the use of inquiry-based methods.

The CAMCC was designed to delineate any mechanisms underlying significant and lasting belief change among teachers. This model looks to describe how teachers’ beliefs about instruction are so resistant to constructivist-oriented reforms and provide a conceptual model for delivering and implementing reform-oriented messages (Gregoire, 2003). This model blends aspects from conceptual change theory and social psychology theory with applied research on teacher beliefs in order to better explain the process of conceptual change in teachers’ instructional practice (Gregoire, 2003).

In order for true conceptual change to occur, a teacher must experience lasting belief change or assimilation of new concepts in comparison to a superficial belief change or accommodation (Gregoire, 2003). These conceptions are likely to exist unless

learners experience successful instructional interventions as transforming one's practice is not accomplished easily or without conflict (Eylon & Linn, 1988; Johnson, 2007). The CAMCC states that teachers being presented a reform message must sense the message as a "stress appraisal" before they will engage in accepting the message.

Systems of teacher beliefs. Downey, Steffy, English, Frase, and Poston, Jr. (2004) estimate that teachers make over 1,000 decisions in a school day. With current demands to differentiate and promote the academic growth of every child, teachers have become even more pressured to make informed decisions regarding instructional practice. In the rapidly changing environment of the classroom, teachers often depend on beliefs in making decisions about practice (Fletcher & Luft, 2011) rather than implementing a step-by-step problem solving process. Wallace and Kang (2004) stated, "[b]eliefs are an important component of practical knowledge and serve as the filter through which practical knowledge is developed" (p. 938). Nespor (1987) first developed a theoretical construct about belief systems and their role in decision-making in the classroom. These belief systems are built upon episodic knowledge, characterized by recalled stories and events, affective elements including feelings about individual students, and attitudes about entities such as immaturity, ability, and laziness. Teachers' decisions about how and when to incorporate inquiry-based practices can be based upon these remembrances, feelings, and presumptions (Wallace & Kang, 2004). Teacher actions are representative of one aspect of teacher beliefs and cannot be seen as a separate entity from the belief system as a whole. For example, science teachers will publically assert they are implementing a reform-based practice, yet their strongly held beliefs about instructional

practice can subvert any efforts of implementation. Therefore, in researching teacher actions, one should also investigate cognitively perceived beliefs to better understand an individual's entire schema. Savasci and Berlin (2012) noted the existence of multiple studies on teacher beliefs and classroom practice, including the area of inquiry. These beliefs about the nature of science can influence the implementation of inquiry-based practice.

Changing teacher beliefs. According to Gregoire (2003), the process of belief change begins with the reception of the reform message. With the presentation of the reform message, teachers view the implications in one of two ways. One way is to view the reform message as already being implemented within their practice (positive-benign) or that the reform message does not apply to or have any impact to their practice (neutral). These perceptions lead to predominantly heuristic processing of the message thereby not promoting teachers to identify cognitive dissonance about their practice. However, if a teacher receives the reform message in a way that initiates a stress appraisal about one's current practice, the teacher will be more likely to be motivated to engage in a reflection of current ideas and how they are in conflict with the presented message. Once a teacher is motivated to challenge her conceptions, she must also have a belief in her abilities to implement the change. Then, the teacher can engage in systematic processing of the reform message leading to an accommodation of the new concepts and a resulting change in beliefs. Otherwise, the teacher will simply assimilate the reform message leading to a superficial change in beliefs, which, in turn will not translate into observed changes in practice. Although this model was developed within a study of

mathematics teachers, the reform message is similar in science teaching in terms of moving teachers to using more constructivist-based approaches within their practice (Ebert & Crippen, 2010).

Role of Reflective Practice Models

As noted within the framework of the Cognitive-Affective Model of Conceptual Change (CAMCC), implementing the steps of the Conceptual Change Model (CCM) by simply activating a learner's prior knowledge, identifying held conceptions, and presenting new information to challenge those held conceptions does not automatically promote accommodation of new concepts regarding instructional practice. The CAMCC posits that when teachers are introduced to a "reform message" or new concept, they must receive that message as a "stress appraisal." This concept of a stress appraisal is complimentary to the concept of cognitive dissonance presented within the framework of the CCM. Therefore, as teachers are observed inconsistently implementing a change within their instructional practice, this model indicates that additional steps need to be taken in order for the accommodation of the new concepts.

To move teachers from achieving superficial belief change/assimilation to obtaining true conceptual change/accommodation, they need support in identifying their efficacy beliefs and available resources to enact the systematic processing needed. According to Johnson (2007), "it takes time to process what is learned in a professional development experience and to internalize it in order to assimilate it into practice, especially if the new concept or strategy challenges the teachers' current beliefs about how science should be taught" (p. 657). Reflective practice is a process by which

practitioners can be supported in making sense of their practice through a process of deliberative examination (Camburn, 2010; Raines & Shadiow, 1995; Schon, 1983).

As part of engaging in a reflective practice model, participating in one-on-one dialogues with a peer or instructional expert can support teachers in the adoption of new instructional methods (Downey et al., 2004). Spending time in dialoguing with an instructional expert can increase the likelihood a teacher will engage in reflective practice and can expose teachers to implementing a new teaching strategy (Camburn, 2010). In addition, the use of a reflective practice model guides the practitioner to uncover both explicit and implicit knowledge (Schon, 1983). Identifying one's implicit knowledge increases a practitioner's awareness of "hidden" knowledge that influences one's held conceptions that informs decisions about instructional practice (Knight, 1996).

Research on cognition provides some key guidelines for promoting dissonance between new ideas and existing ones such as actively engaging teachers in discussion and reflection to challenge existing ideas and construct new ones (Loucks-Horsley et al., 2010). Few teachers can reflect upon their attitudes and beliefs that influence their instructional decisions without having someone engage them in bringing out their deeply held beliefs as they often exist at the subconscious level (Downey et al., 2004). Engaging in reflective practice moves a teacher out of his or her comfort zone by the creation of cognitive dissonance to enable them to "question their behavior, reflect about practice, seek out new knowledge, and change their practice so that more children are learning at high levels" (Downey et al., p. 136). Teachers who are included in some active conversation about their practice such as responding to a variety of questions about their

pedagogy will have more resources for change (Cohen, 1990). “When teachers experience and reflect on how students learn, they are better able to understand why certain instructional strategies are more effective than others, thus enabling them to provide powerful learning experiences for their students” (Loucks-Horsley et al., p. 53). Practitioners who refuse to engage in a reflective practice model are limited in their abilities and can be destructive to others within their profession (Schon, 1983). Johnson (2007) states, “In order to facilitate change in beliefs and practices, professional development providers should include opportunities for teachers to engage in discourse with others…” (p. 657). Reflective dialogue can be a tool to engage teachers in the dissonance/stress appraisal thereby leading to the accommodation of new concepts by taking into account teachers’ emotional and affective reactions along with their cognitive processing of a reform message. Having teachers engage in reflective dialogue can assist in overcoming superficial understandings about their perceptions of inquiry-based instruction as well as identifying the internal and external factors influencing one’s ability to use more effective strategies in science education (Downey et al., 2004; Johnson, 2007). “If the reform message is accepted, but the teachers’ cognitive schema about teaching is not radically altered, true conceptual change has not occurred” (Gregoire, 2003, p. 166). Reflective dialogue can assist practitioners in overcoming this phenomenon, as expressed in observed teachers who are inconsistently implementing inquiry-based instruction. The dialogues can engage the learner in identifying prior knowledge, noting any expressed or unexpressed anxiety or fear regarding the new

information, and helping the learner form a bridge between held conceptions and the reform message or new information. (Camburn, 2010; Downey et al., 2004).

The utilization of reflective dialogue could better enable teachers to move from a state of benign-positive approval into a state of stress appraisal as supported by the CAMCC (Gregoire, 2003). When teachers perceive their abilities are sufficient for challenging their currently-held beliefs and believe they have the capacity to implement the reform message, they can engage in systematic processing thereby leading to lasting belief change (Gregoire, 2003). The use of reflective dialogue can provide the support needed for teachers to acknowledge the reform message, believe in their capability to implement the message, and accommodate the reform message within existing schema. Engaging in reflective dialogues can also challenge a teacher to search for patterns and questioning one's reasons for identifying practice as being effective or unsuccessful (Downey et al., 2004; Raines & Shadiow, 1995).

The questions posed during a reflective dialogues should be centered within the teacher's current range of pedagogical knowledge and professional repertoire. However, these question should also seek to move the teacher out of that comfort zone in order to create cognitive dissonance. This dissonance should "promote intellectual/conceptual/cognitive growth, but not so much as to be overwhelming" (p. 85, Downey et al., 2004). This approach supports the assertions from both the Conceptual Change Model and the Cognitive-Affective Model of Conceptual Change regarding an essential element for the assimilation of new conceptions.

In order for facilitators to form effective reflective questions, they must gather information that might be useful for a teacher to consider about one's decision making practices (Downey et al., 2004). Using brief, frequent walkthroughs of a teacher's classroom allows a facilitator to note how observed decisions are impacting student behavior. The rationale underlying this approach is to enable the teacher to become the reflective thinker rather than having the facilitator of the reflective dialogue direct the analysis of the instructional practice. By establishing a frequent pattern of brief, non-evaluative observations, the teacher's perception of the observations becomes one of normality rather than one of being evaluative, or, even, punitive. This frequent sampling of a teacher's procedures also increases the validity of the facilitator's analysis.

However, teachers in the United States have little time within the school day to engage in professional dialogues about teaching and learning (Nelson, Deuel, Slavit, & Kennedy, 2010). Even when teachers are engaged in dialogue, these conversations are typically hurried, held in public spaces, and are superficial in nature. Even when engaged in professional conversations, established norms within public schools limit meaningful, in-depth dialogue (Nelson et al., 2010). Teachers are often reluctant to share noted limitations within their practice as they perceive these remarks as promoting weakness or incompetency with their practice. This reluctance often keeps teachers from identifying and using evidence from lesson plans or student work in reflecting on their practice (Nelson et al., 2010).

Professional Development and Conceptions about Instructional Practice

Professional development initiatives can serve as a vehicle through which teachers can enhance skills and address ineffective practices (Rebore, 2012). Professional development encompasses any form of training provided to educators regarding the examination, reflection, and improvement of their instructional practice pertaining to improved student outcomes. Professional development can be delivered through various methods such as workshops, courses, collaborative exchanges, or independent study. The primary goal of professional development is to impact student learning outcomes through changing teacher behaviors and, ultimately, improving instructional practices (Gusky & Yoon, 2009). In turn, professional development can also play a key role in impacting overall school success (Schmitt, 2004).

The relationship between professional development and advancing student learning is a complex one. Guskey and Yoon (2009) argue that educators need job-embedded assistance and considerable amounts of structured and sustained follow-up as they struggle to adopt new instructional practices. Whatever their approach, researchers have found it difficult to explain how instruction leads to change in the learner's understanding. Current research indicates a lack of rigorous investigations to relate professional development and student achievement. And, the evidence cited from these investigations (Schmitt, 2004) show no discernible link between improvements in teacher practice and specific student learning outcomes. As student learning takes place in complex environments, it is difficult to ascertain the effectiveness of professional development initiatives. For any professional development initiative to have an impact on

changing teacher practice, the program should be sustained, supported, and adaptive to individual classroom needs (Capps, et al, 2012; Guskey, 2003).

However, student populations within our schools are undergoing tremendous change as students come from more diverse backgrounds. Rebore (2012) writes that public schools have a mandate to prepare our country's students with the skills to cope with these challenges generated by our constantly changing society. In reaction to these challenges brought to our schools, teachers must constantly enhance their skills in order to maintain effective practices while making the necessary changes in one's practice to meet the needs of these students. Without gaining a clear understanding of one's practice and the connections to the instructional decisions being made, a teacher will be ill-equipped to meet the needs of this new generation of students (Downey et al., 2004).

Being able to understand the content at a deep level and the ways students learn that content is a critical attribute of effective professional development (Capps et al, 2012; Guskey, 2003). Involving teachers in gaining a better understanding of the content they teach and how to help their students gain knowledge of that specific content and skills has been shown to best impact changes in pedagogy (Ball, Thames, & Phelps, 2008; Shulman, 1986). Educators need to be able to recognize and challenge the representations, ideas, and beliefs of theories held by their students in order to facilitate connections between prior knowledge and new content (Limon, 2001). In doing this, teachers can begin to interpret students' patterns of thinking in order to facilitate students' development of thinking and problem solving skills (Franke, Carpenter, Levi, & Fennema, 2001).

Professional Development for Inquiry-based Methods

There is limited research in exploring the understandings of practicing teachers implementing inquiry to achieve effective inquiry (Ireland et al., 2012). Various research studies about changes to instructional practice to implement inquiry-based methods, noted several issues: resistance, lack of motivation, and superficial attempts. Even when the professional development being provided to teachers meets the criteria for being effective, there can be a lack of implementation of these inquiry-based methods (Gregoire, 2003; Kent & Crippen, 2010; Marshall & Horton, 2010). Effective professional development in science education is needed for teachers to be more aware of their current practices and identify ways to effectively implement inquiry-based instruction in light of the restrictions imposed by the emphasis on high-stakes testing and accountability as included in the implementation of the No Child Left Behind Act in 2001 (Loucks-Horsley et al., 2010) and the Every Student Succeeds Act in 2015. Capps et al. (2012) formulated an operational definition of inquiry-based science professional development "consisting of activities that support teachers in creating classroom environments in which students learn science concepts and principles through inquiry, as well as learn about what science is, and how scientists work" (p. 296). However, embracing a model of inquiry-based instruction requires changes to the current culture in science education classrooms (Carey, 2000). The process of teaching, especially inquiry, is complex and requires extended time for developing one's instructional practice (Capps et al., 2012; Jeanpierre, Oberhauser, & Freeman, 2005; Loucks-Horsley et al., 2010; Marshall & Horton, 2010). "In order to provide a learning environment in which students

are able to engage in inquiry, teachers are required to have an understanding of what scientific inquiry learning is and what pedagogical practices are necessary to help achieve it in students" (Ireland, Watters, Brownlee, & Lupton, 2012, p. 160).

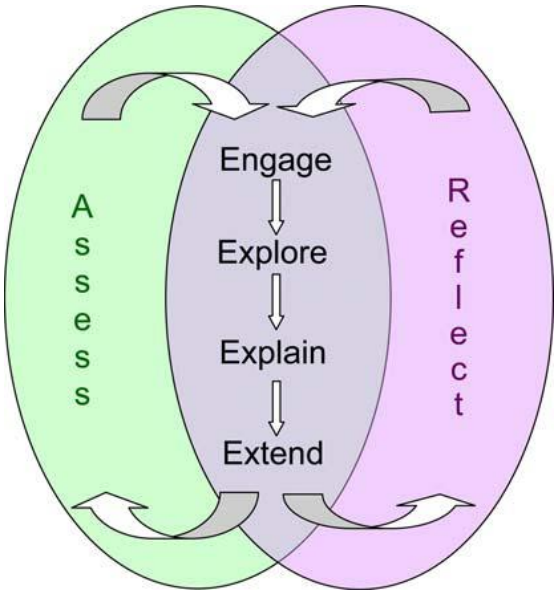
In their review of the literature on professional development for inquiry, Capps et al. (2012) found a continuous need within the field of science education to assist teachers in understanding how to effectively implement inquiry-based practice. Teaching inquiry is a complex and demanding process. Historically teachers did not receive training for implementing these practices nor did they observe their peers using these practices (Wallace & Kang, 2004). Many teachers teach using direct instructional methods similar in the ways by which they were taught (Capps et al., 2012). Sustained and supported professional development is needed to assist in implementing changes in practice (Capps et al., 2012; Guskey, 2003; Johnson, 2007; Wallace & Kang, 2004).

4E x 2 Instructional Model

The 4E x 2 Instructional Model (see Figure 2.1) provides teachers with a paradigm for guiding inquiry-based learning more effectively by intentionally incorporating formative assessment, inquiry instruction, and reflective practice at each step of the pedagogical process (Dong, Marshall, & Wang, 2009). The 4E x 2 model builds upon previous research on existing models of learning that propose creating disequilibrium experiences for students in order to resolve misconceptions and promote full understanding. Many of these existing models, however, do not integrate other essential components identified by learning theorists as needed to foster strong

conceptual understanding and process skill development among students (Marshall, Smart, & Horton, 2010).

Figure 2.1 The 4E x 2 Instructional Model (Marshall, 2007)



The implementation of the 4E x 2 Instructional Model gives teachers a concrete approach to routinely incorporate inquiry-based methods into their daily instruction. The first step in the model is Engage, during which the learners' prior knowledge is activated and misconceptions are uncovered about the big ideas being presented in the lesson. The next step within the model, Explore, involves giving learners opportunities to investigate their ideas and conceptions uncovered in the previous phase in order to construct one's own understandings. The following step is Explain in which both the students and the teacher work in conjunction to construct meaning of the ideas formulated in the previous step. The final step is Extend, which involves students applying their recently constructed conceptions in new situations. In comparison to other learning models such as the 5E Instructional Model (Bybee et al., 2006), the 4E x 2 Instructional Model incorporates the

essential components of formative assessment and reflection at all four stages of inquiry-based learning rather than at the conclusion of the model (Dong et al., 2009). By their continued participation in this professional development initiative, it isanticipated that teachers will be able to translate the practices embedded in the 4E x 2 Instructional Model into their daily practice and thereby guide all students in acquiring robust conceptual understanding and process skill development (Marshall et al., 2009). This approach guides students to become more active participants in their learning resulting in deeper understanding and higher levels of mastery which, in turn, will ultimately enable students to apply these skills to their lives as active members of a global workforce and a complex, ever-changing 21st century society (Gallagher & Stepien, 1995).

Using Reflective Dialogue within Professional Development

When practitioners allow themselves to enter into conflict about their practice, the resulting uncertainty can be perceived as a threat and their admission of these doubts as a sign of weakness (Schon, 1983). The gap created between current practice and professional development cannot be too vast or it becomes disabling (Downey et al., 2004). As a person learns new things, mistakes will be made. However, most schools do not offer teachers opportunities to work through any faults they may have in going through the process (Cohen, 1990). Guskey and Yoon (2009) argue that educators need job-embedded assistance and considerable amounts of structured and sustained follow-up as they struggle to adopt new instructional practices. Teachers need to have opportunities to adapt new practices within their unique classroom context while overcoming feelings of insecurity in their explorations. Using reflective dialogue as part of teachers' analysis

of their instructional practices will enable them to question their practice within a current, established comfort zone to make meaning of their experiences (Downey et al., 2004). As teachers are supported in being reflective about their practice, they will engage in an ongoing process of reflection, renewal and growth (Downey et al., 2004). Engaging science teachers in collaborative, reflective dialogue about their use of inquiry-based practices is one way for them to undertake a critique of the tacit understandings that have developed around repetitive experiences of their practice (Schön, 1983).

Capps et al. (2012) identified some common characteristics of effective inquiry professional development as including extended support, reflection, and transference. In providing extended support, professional development programs were prolonged for a period of time in which teachers were provided periodic workshops or classroom visitations throughout the school year. To encourage reflection, programs included opportunities for teachers to contemplate their instructional practices through dialogue, discussion groups, or journaling. To provide opportunities for transference, programs engaged teachers in explicit discussions about how instructional practices were being enacted within the classroom (Capps et al., 2012). Reflective dialogues can function as a tool to provide these components to existing professional development initiatives. The use of reflective dialogue to engage teachers in the identification of existing misconceptions may lead to the accommodation of the concepts of inquiry-based instruction (Ebert & Crippen, 2010).

Summary

Within the current body of literature, there are few, if any, studies examining the connection between teacher held conceptions about inquiry-based practice and professional development. Most studies examine the impact of professional development on instructional practice focus on teacher beliefs, self-efficacy, and motiviational factors regarding teacher acceptance and participation. However, conceptual understanding forms the hallmark for science teaching and learning, and the literature presented within this chapter supports this framework as an effective model for students to learn science. Therefore, if teachers are expected to lead their students to learn at the conceptual level, the teachers' conceptual understanding about the nature of science and the implementation of inquiry-based instruction should be explored.

The implementation of inquiry-based practice for practitioners can be a difficult process for multiple reasons. a) The concept of inquiry is very abstract and difficult to define; even within the science education community there are multiple interpretations of the concept of inquiry. b) Inquiry is a conceptual model rather than an instructional strategy that can be defined by a straight forward process or mastered through rote learning. Conceptual learning was first described by the Conceptual Change Model (Posner et al., 1982). This model outlines the process by which a learner gradually assimilates a new conception after the identification of and willingness to change held conceptions. Within this process, a learner's prior knowledge must be accessed, identified, and evaluated for misconceptions. Conceptual change then occurs when the learner fully accommodates the new conception in place of the previous held understanding. c) The identification of prior held conceptions and the assimilation of new

concepts is a complex and multiple step process. As one's professional practice becomes more repetitive and routine, it is difficult for the practitioner to recognize opportunities in which to contemplate one's habitual actions. As practitioners, teachers often are reluctant or even unable to recognize the aspects of their instructional practice as they become more adapt and require less cognitive energy to implement day-to-day routines. d) In order for some practitioners to fully accommodate the new concept within currently held conceptions, they also need engagement of their affective domain as demonstrated through the Cognitive-Affective Model of Conceptual Change (CAMCC) proposed by Michele Gregoire (2003). This model suggests that one's affective domain must also be stimulated in order for a teacher to interpret and accept a reform message. Reflective dialogue can be an effective tool in providing that stimulus so that teachers can better accommodate new conceptions about inquiry-based methods.

CHAPTER THREE

METHODS

This study emerged from the researcher's work with a professional development initiative designed to improve both inquiry-based instruction and student achievement involving approximately 100 middle school science teachers over the course of three years. This initiative was developed and sustained through the work of math and science education professors at a state-supported, research university located within the southeastern United States. Participating middle schools in this initiative committed to having math and science teachers participate for an entire academic year. In some of the schools, the entire math and/or science department participated. In other schools, as few as one teacher participated. Participation in the initiative began with all teachers from each of the middle schools within each cohort meeting for two weeks in the summer to study inquiry-based practices and further their abilities in facilitating thoughtful inquiry learning experiences. Participants engaged in discussions regarding time usage, instruction, classroom discourse, assessment, and curriculum as well as how the implementation of these five specific factors could directly impact inquiry-based instruction (Marshall & Horton, 2010). In addition, the participants took on the role of learners in inquiry-based lessons called exemplars, built around the 4E x 2 Instructional Model (Marshall, 2007). During this time, the 4E x 2 model was explicitly modeled for teachers utilizing the steps of the model. After gaining experience with already created exemplars, the participants worked collaboratively to develop new exemplar lessons based on state curriculum standards for use in their classrooms.

During the school year, participating teachers from each cohort met once a quarter after school for approximately two hours during which the teachers shared their experiences in implementing the exemplar lessons developed during the summer institute. In addition, participating schools allowed researchers to observe the teachers once a quarter. These classroom observations were scheduled in advance with each teacher. Each observed lesson was evaluated using the Electronic Quality of Inquiry Protocol or EQUIP (Marshall, Horton, Smart, & Llewellyn, 2008). The EQUIP was developed in response to a noted lack of emphasis of existing instruments to evaluate the quantity and quality of observed inquiry instruction (Marshall, Smart, & Horton, 2010). The instrument can be used to evaluate instructional practice, assess the effectiveness of professional development initiatives, and guide practitioners in reflective dialogue about their practice. Furthermore, the EQUIP was designed for use by various participants involved in inquiry-based education such as educational researchers, practicing teachers, and program reviewers. The EQUIP is comprised of four constructs: instruction, discourse, assessment, and curriculum (see Appendix A). Within each construct, there are five indicators (with the exception of curriculum, which has four indicators). Each indicator is scored along a continuum from pre-inquiry (level one) to exemplary (level four). The goal for participants within the professional development initiative was to score consistently at proficient (level three).

After taking part with this initiative for two years, two participants, who were science teachers from the same middle school, were observed not consistently implementing the structure of the 4E x 2 model and inquiry-based methods within their

instructional practice. The overall EQUIP scores for these participants on each construct either remained at or inconsistently improved beyond the developing level (level two). In addition, these two participants showed a disconnect between their verbal reflections and these EQUIP scores of their implementation of inquiry-based methods.

In order to understand the underlying factors that were influencing the decision-making process of the two participants noted above, this study examined the conceptions of inquiry-based instruction expressed during facilitated reflective dialogues and observed instructional practice. This study took place over the course of a semester at a single middle school located in the southeast region of the United States and engaged the teachers in a systematic evaluation and reflection of their instructional practice as it related to the implementation of the inquiry-based methods.

Specifically, the following research questions were investigated:

1) How do science teachers describe their conceptions of inquiry-based practice during reflective dialogue?

2) How are these expressed conceptions about inquiry-based practice represented in their instructional decision making process?

3) Can engaging in reflective dialogue bring about conceptual change regarding inquiry-based practice?

Research Design

As this study is attempting to investigate a complex phenomenon, the use of a case study research method can best fully describe the experiences, beliefs, and conceptions of these teachers and the real life context in which they exist while being bounded by time and activity. The use of a multi-case study method allows for one to examine individual cases that share common factors such as participation within an

professional development initiative or context such as a middle school science learning environment yet each case can have distinguishingfactors and relationships within the study setting. The two purposefully selected teachers for this multi-case study were a unique subset of the population of participants within their cohort within the professional development initiative. Each selected teacher respresents a single case within this study. The data collected for each case will be examined and coded. Then, all data from each case will be analyzed for emerging themes.

The use of a multi-case design will allow for the capture of rich, descriptive details from an in-depth exploration of the characteristics of both participants. These teachers shared the experience of being situated at the same middle school, being involved within the same cohort of the professional development intiative, and being evaluated on the implementation of inquiry-based methods using the same instrument, the EQUIP. After two years of continuous participation with the professional development initiative, they both were not displaying expected progress in the transformation of their practice. Yet, even though they shared these characterisistics, they both demonstrated distinctive patterns of progress through the end of the second year of participation. Therefore, the use of multi-case design will allow for a comprehensive investigation of these two similar, yet unique cases in order to uncover possible, hidden barriers to the full accommodation of conceptual understanding regarding inquiry-based instruction.

Inquiry-based instruction is a complex process and comprises multiple factors including held conceptions, beliefs, motivational factors, and situational factors. This research design will allow for a comparision of findings from each case in order to

enhance the understanding of these underlying factors that influence one's conceptual understanding of inquiry-based instruction. In addition, the findings will contribute to an overall understanding of how one's held concpetions influence the implementation of new instructional methods.

Utilizing a multi-case design does contribute to the robustness of the findings. However, this study only used two cases as within the context of the overall professional development initiative as only these two teachers displayed the characteristics of inconsistent or no progress within the transformation of their practice. Therefore, the findings from these two cases can only be used to determine for the professional development participants situated within this study site. It is hoped that these outcomes can be use to generate additional hypotheses about middle school science teachers who demonstrate inconsistent progress with the implementation of the 4E x 2 model.

Each participant will comprise a single case that is bounded by time, location, subject matter, and context. Each case was studied with the same time frame of the teachers' third year of participation within the professional development initative. Both participants were teaching at the same middle school and taught science for gifted and grade-level students during the entirety of the study. Both teachers had been identified as making unexpected progress towards transforming their practice with a proficient level implementation of inquiry-based methods. However, the participants displayed unique characteristics regarding that progress. One teacher demonstrated inconsistent transfomations while the other teacher demonstrated a consistant lack of transformation.

Utilizing multiple sources of evidence within a single case has been shown to increase the overall quality of the study as opposed to those studies that only rely on a single source of information (Yin, 2009). Therefore, data was collected from interviews, reflective dialogues, and observed lessons for each case in order to uncover factors that could be contributing to the unexpected levels of progress. Within the analysis for each case, currently held conceptions about inquiry-based methods as well as perceptions about the level of implementations of those methods within one's practice were identified. In addition, these conceptions were assessed for alignment within observed instructional practices and for evidence of conceptual change.

At the conclusion of the within-case analysis for each case, a cross-case analysis was conducted to facilitate a comparison of commonalities and differences in the events, activities, and processes of each case (Stake, 2006). This thematic analysis occurs as all of the findings from both cases will be organized by EQUIP construct and analyzed for commonalities and difference within each construct. Boyatzis defined a theme as "a pattern in the information that at minimum describes and organizes the possible observations and at maximum interprets aspects of the phenomenon" (p. 161). Through a careful and thorough examination and frequent re-examination of the data, an emergence of themes both within each case and across each case will be noted. The coding process employed during these analyses should identify themes from key moments that align or disalign with the four constructs and underlying indicators contained within EQUIP. With this approach to data analysis, these emerging themes then become the unit of analysis (Boyatzis, 1998) within and across the cases.

Researcher Bias

As a qualitative researcher, I recognize the inherent bias that could influence my research and analysis. I worked for over fifteen years in public school systems within the same geographical region of the state where this study took place. During that time, I was employed as a middle school science teacher, instructional specialist, program coordinator, and administrator. As part of these experiences, I collaborated with school and district personnel in designing and providing professional development for K-12 teachers, writing curriculum guides for middle school science, and reviewing state benchmark assessment items. In my experiences with providing professional development, I utilized interventions with teachers that involved various protocols of reflective practice. While working as an instructional specialist in math and science, I would formally observe teachers and then engage with them in a 30-40 minute dialogue to reflect on an area of strength and an area of improvement. I was formally trained in using that protocol and underwent a recertification process at the start of each school year in order to establish inter-rater reliability with the instrument.

In addition, I began working with the two participants taking part in this study within the role of a graduate assistant who worked with facilitating the summer institutes, observing lessons, scoring the lessons using EQUIP, and providing support with instructional planning as part of the ongoing professional development initiative. Therefore, I began this study with previously held conceptions about the use of reflective practice models within teacher professional development initiatives. I also had significant experience in working with the two participants and evaluating the quality of their

implementation of inquiry-based practice. These prior experiences could be interpreted as a source of bias within the research.

Theoretical Framework

Conceptual change theory argues that learners must engage with their prior experiences and understandings before successfully making accommodations to those conceptions leading to a significant change in behaviors, or in this study, instructional practices (Posner et al., 1982). Consequently, one must first identify prior knowledge and currently held misconceptions that have been built from assimilation of the concepts in order to enter into a reflection of those conceptions with the goal of obtaining lasting conceptual change. Without the acknowledgement of these concepts, the participants in this study will continue to engage in heuristic processing of the ideas and concepts presented in the ongoing professional development initiative. They will continue in an experiential mode of implementation and be unable to engage in the needed dissonance required for the accommodation of new concepts. Therefore, these participants were engaged in a series of reflective dialogues designed to identify misconceptions about inquiry-based practice in order to lead them in undergoing a change to their currently held conceptions. Once any misconceptions were identified, participants were led to reflect on the existence of these concepts and how those concepts would not be in alignment with the inquiry-based practices presented within the professional development initiative. In addition, the participants were engaged in experiencing some dissonance about one's pedagogical content knowledge (PCK) that was not directly in line with inquiry-based practice in order to build a strong link between inquiry-based instruction

and observed practice. To assist with this reflection of current practice, evidence of how those misconceptions influenced the participant's decisions about instructional practice was collected from classroom observations and accompanying instructional artifacts. Each participant's progress in implementing these more rigorous and authentic learning experiences and developing competencies in using inquiry-based methods was then assessed.

Research Setting

This study took place in a grade 6-8 middle school located in an urban school district located within a southern city of approximately 25,500 residents of whom 63.1% were White and 36.9% were African-American/Other (www.citytowninfo.com). At the time of this study, this school had 660 students enrolled of whom 55.4% were White and 44.6% were African-American/Other (www.advanced-ed.org). Therefore, this school had a higher percentage of minority students enrolled than represented within the city population. The poverty index for this school was at 80.62% although the school did not have Title I status during the time of this study.

Also, at the time of the study, this school was transitioning into a STEM-based magnet school within the local school district. As part of this transition, the school began offering STEM elective courses and advanced science core academic courses. In addition, during of the study, all middle schools within the district underwent a rezoning process as a result of the addition of two new middle schools. Also during this rezoning process, each of the district's middle schools were given a specialty theme and a school choice plan was implemented to allow families to select which of the five schools to send

their students. Prior to the rezoning, the school enrolled approximately 1,050 students. Afterwards, the enrollment declined to 660 students as the existing school population transferred to the newer schools or to a school with a different focus such as arts or leadership. This time of transition impacted every stakeholder and elicited feelings of uncertainty for all faculty and staff.

Study Participants

During the first two years of the researcher's involvement with the professional development initiative with this particular middle school, all of the teachers within the science department had chosen to participate in the professional development initiative. Support was continually provided to all participants during the school year through giving feedback from observations of full-length lessons taught by participants, meeting with participants to plan inquiry-based units and lessons using the 4E x 2 model, and holding follow-up meetings for participants to review and analyze their practice.

The two teachers, Ms. Carroll and Ms. Newman, were purposefully chosen for this study based on the observed implementation of inquiry-based methods over the course of their first two years of participation within the professional development initiative. Both teachers had self-selected for multiple years of participation in the professional development initiative and worked at the same middle school for many years prior to the study. In addition, these two teachers were the only ones who taught on-grade level and gifted/talented grouped classes within the same grade level as well as teaching multiple grade levels within the same academic year.

The participants differed in their educational backgrounds and years of teaching experience (see Table 3.1). Ms. Carroll held a degree in elementary education, and Ms. Newman held a degree in biology and National Board certification in early adolescence/science. However, both teachers expressed similar levels of understanding of the content and the nature of science. In addition, both teachers articulated similar levels of pedagogical content knowledge within the sciences. Due to their daily schedules, these two teachers did not share a common planning time and were not able to collaborate during the school day.

Study Participant	*Years of teaching experience*	*Number of years at study location*	*Highest degree obtained*	*Certifications Held*
Ms. Carroll	15	12	Bachelor's Degree- Elementary Education	Middle level science, gifted and talented endorsement
Ms. Newman	30	20	Bachelor's Degree- Biology	Middle level and secondary level science, gifted and talented endorsement, National Board Certification in early adolescence/science

Table 3.1: Study participants' education experience

Study Context

This study is an off-shoot of a larger study being conducted among all schools involved within the professional development initiative. Details of this larger study can be found in an article by Marshall and Alston (2014). With the challenges this school was facing during the PDI due to rezoning and a rise in the poverty index for students, a need was identified for these teachers to gain a full understanding of how to effectively and consistently implement inquiry-based practices to meet the needs of their students. When two teachers from this group were identified as not making sustained transformations within their practice, an intervention was sought to identify possible sources for the resistance.

This study was then embedded within an ongoing multi-year professional development initiative in which all of the science teachers from this school were involved for two years prior to the start of this study. During the first year of participation, multiple data sources for all eight of the science teachers from this middle school at which the current study took place were analyzed for evidence of teachers' understanding of the concept of effective inquiry-based practice as defined by the 4E x 2 model. From this analysis, six teachers were selected to participate in a pilot study in the use of reflective dialogue. These dialogues were held before and after observed lessons conducted as part of the overall PDI. Two of the purposefully selected teachers within the pilot study demonstrated continuous improvement in their understanding and implementation of inquiry-based practice. Two of the teachers demonstrated some improvement and the two

remaining teachers demonstrated little or no change in their understanding and implementation.

All eight science teachers (including the six who had participated in the pilot study) returned for a second year of participation within the PDI. These teachers were asked to further develop their instructional practice with the goal of consistently implementing inquiry-based practices at a proficient level as defined by the EQUIP. In addition, they had to develop specific professional development goals. Some of the teachers developed goals for which they would continue participating in informal reflective dialogues regarding lesson planning, implementation, and assessment.

At the time in which this study was conducted, four teachers from this middle school self-selected to continue in a third year of participation in the professional development initiative. Of these four teachers, two were on track in meeting the goals of consistently implementing inquiry-based practice at the proficient level so there was no identifiable need for them to participate in the study intervention. However, two of these teachers presented a unique situation in which they were observed as inconsistently implementing proficient inquiry practices. Therefore, to better understand their difficulties, this study was conceptualized in order to understand how to best support their learning. Throughout their participation within the professional development initiative, these teachers were required to develop and implement exemplar lessons based on the 4E x 2 Instructional Model. Observations of their exemplar lessons were scored primarily at the developing level on EQUIP through the end of the second year although in post observation conversations, these two teachers viewed their implementation as proficient.

During classroom observations and instructional planning sessions, these teachers were unable to articulate an understanding of the new concepts presented within the professional development initiative. Therefore, an intervention was sought to uncover factors that were acting as barriers to sustainable transformation of practice for these two teachers.

Throughout this study, the rights of the study participants were protected by having an approved IRB protocol for human subjects research. As part of this protocol, permission was given to audio record all interviews, reflective dialogues, and observed lessons. Both participants signed a consent to participate form and were counseled regarding their rights to withdraw from the study at any time with no punitive measures. However, permission to video record was not obtained in order to maintain the anonymity of all students within each participant's classrooms. All audio files were saved using a unique file name that did not reference the name of the teacher. These files will be destroyed upon the completion of this study.

As the school site used within this study was already participating in the overall professional development initiative, permission was granted by the principal investigator of the PDI and the school administration to conduct the research. The two teachers purposefully selected for this study had been identified through an analysis of previously collected data from observations of their practice during scheduled lesson evaluations as part of data collected for the PDI. In addition, these two teachers had been part of the pilot study conducted during the school's first year of participation within the PDI; therefore, they had gained a level of familiarity with the use of reflective dialogue. These

two teachers also constructed professional development goals within their second and third year of participation that allowed for the researcher to observe within their classrooms to provide support in developing lessons that fully embraced the 4E x 2 model.

Data Collection and Analysis

Data Collection

Being able to develop a full understanding of these two cases requires the researcher to experience the actions and events of the case as they occur within that particular context and situation (Stake, 2006). Therefore, data were collected from multiple sources for each case to provide a more thorough examination of teacher conceptions and implementation of inquiry-based practices (see Table 3.2). These data sources included semi-structured interviews, one-on-one reflective dialogues, formal classroom observations and accompanying scores from the EQUIP, field notes from observed lessons based on the 4E x 2 Instructional Model, and instructional artifacts such as lesson plans and worksheets. These qualitative data were collected in order to provide a robust analysis of teacher perceptions as compared to observed implementation of inquiry-based methods. All reflective dialogues and the interviews were recorded and transcribed in their entirety. Field notes were also taken during each session and were referred to during the transcription process to verify any portions of the recording that were vague or inaudible. This protocol was designed to be flexible enough to accommodate any situational factors that arose which impacted the availability of the teachers to schedule and/or participate.

Data source	*Frequency*	*Participants*	*Purpose*
Interviews	Two times (at the start and conclusion of study)	Researcher and teacher	Evidence of teacher conceptions
Reflective dialogues	Seven to ten times	Researcher and teacher	Evidence of changes in teacher conceptions
Formal classroom observations	Three times	Researcher, teacher, and students	Evidence of teacher behaviors
Informal classroom observations	Four to six times	Researcher and teacher	Evidence of teacher behaviors
Instructional artifacts	Seven to ten times	Teacher	Evidence of teacher outputs

Table 3.2: Data Collection Framework

Interview procedure. Participants were interviewed at the start and at the conclusion of the study. These interviews were conducted outside each teacher's daily schedule of classes in order to provide more time for conversation than could be obtained during a teacher's planning period within the school day. Within these sessions, the researcher conducted structured, open-ended interviews. These interviews were audio recorded and field notes were taken. The recordings were transcribed by the researcher, and the transcriptions were continuously checked by frequently reviewing the audio files and comparing the transcription. Additionally, transcriptions were checked for accuracy by reviewing the completed document against the field notes. The transcripts were read and coded for evidence of themes based on the nineteen indicators found within the four constructs of the EQUIP. Within this analysis, areas of proficiency and areas for improvement were noted.

An introductory interview was conducted at the start of the study with each participant in order to obtain information about her conceptions about instructional practice as it related to inquiry-based instruction. This stage-setting baseline interview happened prior to any other research activities. The interview included questions designed to uncover prior knowledge and currently held misconceptions that had been built from an assimilation of the concepts of inquiry-based practice. These questions were designed to align with the four constructs of EQUIP (see Appendix B). Questions were also asked for the purpose of goal setting, planning and implementing inquiry-based instruction, and defining the roles of the teacher and student during these inquiry-based lessons. Teachers were asked to reflect on how they perceived their instructional practice

changing since beginning their participation within the professional development initiative. They were then asked to describe the impacts they had seen on student learning as well as note any advantages and disadvantages for students as a result of implementing those changes. Finally, teachers were asked to list areas within their instructional practice they wanted to address during the course of the study. This information obtained during this initial interview and from classroom observations conducted in the previous semester informed the direction of the first reflective dialogue conducted with each participant.

Both teachers participated in a formal, structured interview at the conclusion of the study. They were asked the same questions as were posed in the initial interview. The themes identified within transcripts of these interviews were compared to the identified themes from the initial interview to uncover evidence of sustained changes to held conceptions about practice.

Reflective dialogue procedure. Following the initial interview, both teachers were invited to participate in a continuing cycle of reflective dialogues. These dialogues were scheduled to occur before and after an observed lesson. All dialogues took place within the teacher's classroom and each dialogue lasted approximately 20-30 minutes. These dialogues occurred every eight to ten school days during the course of the study. This cycle of reflective dialogue was repeated two times during the study for each participant. While two dialogues were scheduled for each of the three observed lessons, the actual number of dialogues that occurred were based on the needs of the individual teacher. The researcher made herself available based on the need of each teacher and by invitation. The overall number of reflective dialogues facilitated for each participant

during this study was decided by researcher based upon the verbalized needs of the participant. As the data was reviewed and analyzed at the conclusion of each dialogue, the researcher then made a determination as to the date of the next scheduled observed lesson as well as the pre-lesson dialogue and post-lesson dialogues for each participant. In some cases, situational factors made the need to delay the next scheduled round of dialogues and observed lesson. In other cases, the participant requested to have the researcher follow-up immediately after the observed lesson and then again after the participant modified the lesson. Overall, Ms. Carroll participated in seven dialogues and Ms. Newman participated in ten dialogues.

The dialogues held before a lesson were used to set goals and articulate instructional plans to be implemented in the next few lessons. Then, participants were observed in order for the researcher to evaluate the degree of proficiency in which the teacher was able to implement inquiry-based instructional practices. Each reflective dialogue was audio-recorded and field notes were taken. The recordings were transcribed by the researcher, and the transcriptions were continuously checked by frequently reviewing the audio files and comparing the transcription. Additionally, transcriptions were checked for accuracy by reviewing the completed document against the field notes.

These reflective dialogues were used to further probe teacher conceptions about the specific practices related to inquiry-based instruction identified within the pre-study interview (see Appendix C). Once any misconceptions were identified, participants were guided to reflect on the existence of these conceptions and how those conceptions were not in alignment with inquiry-based practices. These misconceptions were analyzed for

evidence as barriers for the implementation of practice. In addition, the reflective dialogues focused on engaging the teacher in experiencing some dissonance about one's pedagogical content knowledge (PCK) that was not directly in line with inquiry-based practice.

The reflective dialogue protocol utilized in this study was based upon the Downey Walk-Through and Reflective Practice Approach (Downey et al., 2004). This approach was developed by Carolyn Downey as part of her work as a school administrator starting the 1960s and continuing into the 2000s. The overarching purpose of the Downey model is to engage teachers in reflective dialogue about past decision-making processes in order to guide future practice. By utilizing this reflective approach, teachers are placed in a growth mindset environment and begin to self-monitor their decision making processes and their resulting impact on student learning. Within the Downey model, placing practitioners within a growth mindset connects with the identified need to recognize the impact of the affective factors from the CAMCC (Gregoire, 2003) on teacher beliefs and motivation. The use of this particular reflective dialogue model provides the vital support for teachers to engage in the careful analysis of held conceptions while promoting the dissonance needed to bring about the reorganization of one's held conceptions. Without encountering dissonance to one's held conceptions, the full accommodation of new concepts cannot occur (Posner et al., 1982).

This approach starts with the observer conducting frequent, such as eight to ten, brief classroom visits of approximately two-three minutes in duration. During this time, observers are not to evaluate the teacher. Instead, the purpose of these brief walk-

throughs is to "gather information about curricular and instructional teaching practices and decisions teachers are making" (Downey et al., 2004, p. 2). The end goal of using this approach is to impact student achievement through the identification, analysis, and reflection of the teacher's actions.

The reflective dialogues that follow a series of brief classroom visits are designed to foster collaborative, thoughtful interactions. These interactions encourage intrapersonal change while identifying the teacher's level of expertise and readiness for self-direction. The goal of these dialogues is to influence teacher thinking about one's instructional practice rather than directly modify teacher behavior. By drawing the teacher's attention to their decision-making process, the reflective dialogue is designed to encourage the teacher to identify ways in which he/she can alter one's decisions in order to better impact student achievement.

Downey et al. (2004) has identified three stages of reflective dialogue interaction: direct, indirect, and interdependent. At the start of this study, the researcher identified both participants as aligning with the indirect model in which the observer asks the teacher to reflect on a segment of observed practice and follows up the response with additional questions designed to direct the teacher to evaluate his/her decision making processes. These teachers were fairly confident in their abilities and wanted to identify aspects of their practice that did not align with the attributes of proficient inquiry as defined by the EQUIP. The dialogue concludes with the observer asking the teacher a final reflective question in order to move him/her into an interdependent dialogue interaction. In this type of dialogue, the observer poses a reflective question to the teacher

and allows the teacher to take control of the direction of the dialogue based upon their reflections.

One of the key aspects of the Downey model is the reflective question asked at the start of the dialogue. Within this model, there are five key attributes to crafting a reflective question: identify the situation for the instructional practice, prompt reflection, distinguish criteria, define the decision, and identify the impact on students. By utilizing this protocol, teachers are prompted to engage in analytical thought about one's practice without the context of being an interrogation. However, by engaging a teacher with this reflective question can more engage a practitioner in the needed dissonance to begin the process of conceptual change (Gregoire, 2003; Posner et al., 1982). These reflective questions are generated by data gathered during the brief observations. For example, the following question was used to start each reflective dialogue:

> In planning your lessons [identify the situation] and thinking about implementing inquiry-based instruction [prompt reflection], what factors [distinguish criteria] influenced your decisions about your instructional practice [define decision] to help students construct understanding in today's lesson [student impact]? (see Appendix C).

The focus for each subsequent reflective dialogue was developed on the basis of teacher responses from previous dialogues during which existing misconceptions and perceived areas of refinement were identified. In addition, specific indicators from the EQUIP were chosen as a focal point for continued reflection. During the dialogues, teachers were asked to reflect on the way in which they approached instructional

planning based on their conceptions about inquiry-based instruction. They were asked to articulate their reasoning in support of the decisions they made to implement their instructional practice based on noted teacher behaviors during classroom observations. The perceived impacts of those decisions were discussed in light of student understanding and achievement. Then, teachers were asked to reflect on areas within their instructional practice that could be refined. In focusing on this area, the teacher and researcher discussed specific instructional strategies to be used in the next unit of instruction to address noted areas of refinement. These dialogues were used to guide participants in refining their goals and craft out plans for the next set of lessons. These dialogues also allowed the researcher to continually provide scaffolding for each teacher as she continue to refine her decision-making processes regarding the use of inquiry-based instruction.

Observation procedure. Each participating teacher was informally observed between five and seven times throughout the semester. In addition to these informal observations, each teacher had three lessons formally observed and scored using the EQUIP. During the study, field notes were recorded during all classroom observations. Each classroom observation was scheduled in advance in consultation with the participating teacher. During the lesson, the researcher sat unobtrusively in the classroom and scripted the entire lesson. While scripting, the researcher recorded dialogue between the teacher and students, noted teacher given directives, and listed examples of appropriate and inappropriate student behaviors. As example of a segment from a scripted lesson is as follows:

> Class begins with teacher questioning students about material covered in previous lesson on plate tectonics. She demonstrates by modeling the different types of plate movements on the Smartboard. She asks the class five recall and basic comprehension level questions about these concepts. Students write their answers on paper (Researcher field notes, February 18, 2013).

In addition to scripting the lesson, during the observation, notations were made every five minutes to identify the context in which key elements that directly impact instruction were present in the classroom. At the conclusion of the observation, the lesson was scored using the EQUIP to determine the level of implementation of the inquiry-based practices outlined within the 19 indicators.

Instructional artifacts were also collected for analysis. These items included lesson plans, student worksheets, project handouts, and scoring rubrics. The artifacts provided evidence of teacher outputs following each reflective dialogue. The items created by each teacher served as an indication of how practice was implemented beyond classroom observations.

Electronic Quality of Inquiry Protocol (EQUIP). The EQUIP consists of four pedagogical constructs closely connected to high-quality inquiry-based practice: instruction, discourse, assessment, and curriculum (Marshall et al., 2010). Within each of these constructs, there are five factors with the exception of curriculum, which has four, that further define the components of each construct (see Table 3.3). Each factor has a descriptor describing the quality of the observed practice ranging from pre-inquiry (level one) to exemplary inquiry (level four) to clearly distinguish between levels of

performance (Marshall et al., 2009; Marshall et al., 2011). Each factor is then scored indicating the level of implementation for that specific factor. Then, each of the four areas is given a composite score using the same pre-inquiry to exemplary inquiry scale. In using this design, the EQUIP gives practitioners, administrators, and researchers alike specific behaviors to target in assisting teachers to move towards proficiency in their inquiry-based practice. The factors and descriptors for each of the four constructs can be found in Appendix A.

Construct	*Number of indicators*	*Factors associated with inquiry-based instruction*
Instruction	5	Instructional strategies
		Order of instruction
		Teacher role
		Student role
		Knowledge acquisition
Discourse	5	Questioning level
		Complexity of questions
		Questioning ecology
		Communication Pattern
		Classroom interactions
Assessment	5	Prior knowledge
		Conceptual development
		Student reflection
		Assessment type
		Role of assessing
Curriculum	4	Content depth
		Learner centrality
		Standards
		Organizing and recording information

Table 3.3: Overview of the EQUIP

EQUIP was chosen for use in this study as an instrument that can more effectively facilitate dialogues between researchers and practitioners than other published instruments. In a comparison study by Marshall, Smart, Lotter, and Sirbu (2011), the EQUIP has been shown to be a more valid instrument than The Reformed Teaching Observation Protocol (RTOP) in measuring the quality of inquiry-based instruction. In addition, in comparing the inter-rater reliability scores for both instruments, the scores on EQUIP were consistently higher than on RTOP, even from a team of researchers who had been consistently using the RTOP to observe middle school teachers (Marshall et al., 2011).

According to Marshall et al. (2011), the target level of performance for observed inquiry practices is identified as proficient inquiry (level three) on EQUIP. Proficient inquiry practices as listed on the EQUIP include actively engaging students as learners, asking students to explore a concept before an explanation is provided, successfully engaging students in open-ended discussions, asking students to justify their responses, implementing formative assessments and using the data to inform future instructional decisions, and providing lessons in which students explore concepts with depth. In addition to the scores obtained from observed lessons, field notes taken during classroom observations conducted in previous semesters were used to establish a level of implementation of inquiry-based methods. The EQUIP scores for these teachers at the end of the second year indicated inconsistent growth towards proficient levels of implementation within all four constructs of the instrument.

Data Analysis

According to Stake (2006), the issues embedded within case studies reflect complex, situated, problematic relationships. Therefore, the data collected from both participants, which comprised each case, were analyzed in order to examine the relationship between the participant and the implementation of inquiry-based instruction within the confines of the participant's classroom within the framework presented by the professional development experience. By acknowledging the context and situation of the activities within each case, one can derive an understanding of how those activities are shaping the underlying experiences and resulting interpretations (Stake, 2006).

Unit of analysis. Each participant comprised a single case within the study. Each case was bounded by the context of the classroom and the interaction of the teachers within that instructional environment. Within each case, all data were analyzed for existing themes or issues (Creswell, 2009) based upon each of the four constructs comprising the EQUIP. For each of these constructs, the data collected from each teacher participant (see Table 3.2) were analyzed and coded according to the levels of proficiency for each instructional factor (see Table 3.3) as defined by the EQUIP. Finally, the data were examined for information that was unexpected, unusual, or of interest.

Coding procedure. An *a priori* approach was used to develop the coding structure for the analysis of the interviews/reflective dialogues (teacher conceptions), field notes from classroom observations (teacher behaviors), and instructional artifacts (teacher outputs). Within this coding structure, all noted teacher conceptions, behaviors, and outputs were classified according to the factors for each construct from the EQUIP. Although EQUIP is constructed to evaluate inquiry-based practice at four levels of implementation, the analysis of data was conducted primarily using the descriptors at the developing inquiry and the proficient inquiry levels for each of the 19 factors within the four constructs (instruction, discourse, assessment, and curriculum). These levels of implementation were chosen based on the assessed levels of implementation for each teacher prior to the start of this study. Both teachers had demonstrated inconsistent implementation ranging between the developing inquiry and proficient inquiry levels within the same factors. Using the EQUIP allows for identification of the level of transference of identified conceptions into instructional practice, which aligns with the

stated goal of teacher involvement within the professional development initiative. This goal was to provide experiences for teachers to identify, define, and implement high-quality inquiry-based practice as defined by the EQUIP.

After the initial analysis of the data was complete, noted teacher conceptions regarding levels of implementation were compared against observed behaviors within the classroom using each of the four EQUP constructs: instruction, discourse, assessment, and curriculum. These comparisons were analyzed for evidence of alignment between the teacher conceptions as expressed in the dialogues and teacher behaviors as demonstrated in the observed classroom behaviors and outputs (instructional artifacts) in order to detect any discrepancies. Utilizing an open coding approach, patterns/themes underlying the instructional decision making processes regarding the use of inquiry-based practice for each teacher were noted (Boyatzis, 1998).

These identified themes were analyzed multiple times to establish noted patterns from the primary analysis. The interviews and dialogues were analyzed for evidence of currently held conceptions about inquiry-based practice. Participant statements were evaluated in terms of the level of implementation of inquiry-based practice as reflected in the EQUIP. Over time, these statements were analyzed to assess if these conceptions changed and, if so, were the conceptions reflecting a progression towards more proficient levels of inquiry-based practice. Overt misconceptions about inquiry-based practice were also noted. The observed teacher behaviors noted during classroom observations were assessed for the level of implementation of inquiry-based practice and for alignment of the stated conceptions within observed practice. Evidence of how identified

misconceptions manifested in teacher behaviors during classroom observations were also noted. Finally, all data sources were analyzed for evidence of conceptual change within teacher perceptions, behaviors, and outputs. Conceptual change was defined as the release of identified misconceptions and assimilation of new conceptions as evidenced by changes in behavior, perceptions, and outputs. To ensure the validity of these assertions, the data were analyzed through the process of triangulation. "Triangulation has been generally considered a process of using multiple perceptions to clarify meaning, but it is also verifying the repeatability of an observation or interpretation" (Stake, 2006, p. 37).

Data Verification Procedures

Clarification of researcher bias. During the study, the researcher also served in the position of professional development provider and data collector for the overall study regarding the entire professional development initiative. Therefore, during the analysis of the data, the researcher had to frequently self-reflect on coding and identifying themes in order to ensure an objective analysis. However, as the researcher was able to interact with the two study participants while in multiple roles allowed for the creation of an open and honest narrative that resonated with the teachers. Possessing a high quality of reflectivity from many prior experiences in utilizing and facilitating reflective practice models allowed the researcher to enhance the quality of the findings for this specific study.

Validity. At the study site, there was 100% participation of the science department within the overall professional development initiative. By having all of the science teachers at the study site involved with the PDI, the researcher had open access to classrooms, instructional planning meetings, and conversations with school

administrators. Therefore, the researcher had opportunities to spend prolonged time at the study site as well as observe the multiple instructional environments for the study participants. Having these opportunities allowed the researcher to have increased understanding of the many factors comprising the participants' environment within the field. This enhanced understanding allowed the researcher to draft rich, thick descriptions in conveying the findings. However, these findings can only be generalized to schools with similar characteristics and situational factors.

Interrater reliability. For this study, the researcher served as the sole collector for all sources of data. To establish trustworthiness of the coding process, the researcher maintained a reflective journal on all transcribed data indicating how data was identified using the nineteen factors within EQUIP. The researcher received training on a yearly basis for inter-rater reliability on the use of the EQUIP. The researcher observed and scoreed at least two lessons along with one other member of the professional development initiative team. For the three years the researcher underwent this certification process, all her scores were within the acceptable limits for the PDI data collection requirements. These limits were defined as being no more than one scoring level different from the other rater of each observed lesson. Over the course of the three years participation with the professional development initiative, the researcher observed and scored over 120 observations of instruction within at least 20 different classrooms. All of these data collected were compiled into a larger database for aggregation within the study of the overall professional development (Marshall & Alston, 2014).

Member checking. Field notes and transcripts of classroom observations were reviewed with the study participants during reflective dialogues as the line of questioning within each dialogue built upon the information gathered in previous dialogue. However, due to the nature of this study, analysis of coded data was not shared with study participants as the data were being studied for evidence of inconsistent transformation of practice. The researcher's interpretation of the participant's practice could have been perceived as negative thereby influencing the participant's willingness to continue with the study. In addition, scores from observed lessons using the EQUIP were not shared with the participants as this framework is intended to serve as a benchmark of one's progress in the implementation of inquiry-based practice rather than as a definitive score (Marshall et al., 2009).

The researcher had experience in utilizing the EQUIP in over 200 observed lessons and was able to create a coding structure from a protocol in which she had demonstrated a level of high proficiency. In addition, the researcher utilized peer debriefers who reviewed and asked questions regarding the analysis of coded transcripts. The use of this clarifying process makes the findings of this study more transparent and explicit for other researchers who can verify what was done within this study. The findings were analyzed in a way for interpretation beyond that of the researcher.

However, the process of having coded data checked by either study participants or other researchers is a flaw within the analysis of this study. There was no mechanism in place to check for human error. As this study was only analyzed by a single coder, the findings from this study can only be replicated by the researcher as there was no

opportunity for codes to be cross-checked. In addition, at the time of this study, only a few people had a similar level of experience in utilizing the EQUIP and thus would have had limited expertise in the interpretation of the transcribed data.

In addition, all audio recordings were transcribed by the researcher who was present during all sessions with the study participants. Therefore, the researcher was able to recreate the situation in which these sessions took place thereby eliminating a source of drift within the coding of the transcripts. Also, these transcripts were reviewed by the researcher for evidence of comprehensiveness and correctness. This review was also used to ensure every piece of audio was included within the transcripts. The transcripts were checked for the inclusion of verbal and nonverbal communication noted within detailed descriptions included within the field notes from audio recorded interviews, dialogues, and observed lessons. Field notes also contained information about various environmental factors that were present during each audio recorded session such as noted classroom interruptions, changes to the classroom structure or schedule, and instructional artifacts shared.

Summary

This chapter outlined the methodological approach for this multi-case study including research design, data collection, and data analysis including the coding procedure. For this study, evaluation of the reflections and observed practice within the framework of the four constructs of the EQUIP provided the primary unit of analysis within each case. The data collected were analyzed first by construct and then the data coded for each construct was coded again by the factors comprising each of the

constructs: instruction, discourse, assessment, and curriculum. Triangulation of the data is demonstrated through the use of multiple data sources establishing inter-rater reliability, and member checking. In-depth examination of all of these data sources indicated that as the study participants were able to more effectively articulate the reasoning for their instructional decisions, their implementation of inquiry-based methods became more consistent with a proficient level as defined by EQUIP.

CHAPTER 4

FINDINGS AND ANALYSIS

Within this study, data were collected from three sources for each participant: pre and post interviews; reflective dialogues; classroom observations and instructional artifacts. A multiple case study approach was employed with each teacher participant comprising a single case. Within each case, the data were analyzed in order to examine each teacher's current conceptions about inquiry-based methods as well as the impact of those conceptions on decisions made regarding the implementation of inquiry-based instruction. Analysis of the data looked for evidence of held conceptions about effective inquiry-based practice as defined by the 4E x 2 Instructional Model. Observed classroom lessons were evaluated for evidence of the implementation of those held conceptions. These lessons were also evaluated for evidence of held conceptions that were impacting the effective implementation of inquiry-based practices. Observed practice and instructional artifacts were assessed for proficient levels of implementation within each of the four constructs of the EQUIP in order to measure consistent transformations in practice (Marshall, Horton, Smart, & Llewellyn, 2008). In turn, several recurring themes regarding held conceptions about inquiry-based instruction emerged for each participant.

Study Participant #1-Ms. Carroll

Ms. Carroll taught two sections of on-grade level and three sections of gifted and talented 8th grade science classes. In her on-grade level science classes, students were heterogeneously grouped and several students had IEPs for accommodations in accordance with noted learning disabilities. The students in her gifted and talented classes

were more homogenously grouped. All of students categorized as gifted and talented were identified by the local school district using specific criteria regarding their aptitude and cognitive abilities.

Held Conceptions and Representations within Instructional Practice

From the analysis of the data, Ms. Carroll demonstrated a strong understanding of the concepts of inquiry-based instruction as presented within the 4E x 2 model. However, these understandings were inconsistently reflected within her observed instructional practice. There appeared to be a lack of connection between her conceptions and her implementation. As evidenced from this analysis, Ms. Carroll exhibited four consistently held conceptions about inquiry-based instruction. The first identified conception regarded the order of instruction as exemplified by the 4E x 2 model-engage, explore, explain, extend. The second identified conception regarded the role of the teacher as one of facilitator rather than giver of knowledge. The third identified conception regarded the purpose of formative assessment. The fourth identified conception regarded planning of instruction around key concepts. In addition, two held misconceptions emerged from Ms. Carroll's reflections during facilitated dialogues. These misconceptions were also observed impacting her decision making processes for instruction.

Conception #1-Order of instruction. Within the interviews and reflective dialogues, Ms. Carroll expressed and maintained held conceptions about instructional planning that aligned with proficient level inquiry-based practices. As stated within the instruction construct of EQUIP, proficient implementation of inquiry includes sequencing

instruction to engage students in investigations that allow for an exploration of the concepts before receiving the explanation.

In the introductory interview, Ms. Carroll was asked to reflect on her overall approach to planning for instruction. When asked to explain what she was "doing differently with [her] lesson plans in terms of sequencing [as a result from the PDI]," Ms. Carroll described her approach to plan a lesson about plate boundaries. She stated:

> We've changed the sequence a little bit. Normally, we would introduce them to the layers and let them read about the layers and gather the information to diagram [the layers] themselves. This time, we went from the aspect of what scientists have actually done to determine or discover about the layers of the Earth. We looked at some simulations that were drawn up based on the data that's been gathered to determine not only how many layers there are but in what state they tend to be in. The kids made observations of the simulations to draw conclusions about how many layers and what the state of matter they are in. Then, they went back and gathered more specific evidence about thickness, temperature, and composition. So, we kind of did where they were investigating to some degree because they weren't just told here are the layers and this is how we know it. Almost like they were pretending they were the scientists and discovering it for themselves (Carroll, interview, February 18, 2013).

Her comments during this reflection about her instructional planning provided evidence of a held conception about the order of instruction as aligned within the 4E x 2 Instructional Model. As shown in her comments above, Ms. Carroll described how she first engaged the students in the learning and then gave them time to explore the concept. The instructional opportunities implemented within this lesson allowed students to be actively engaged and explore the concepts of indirect observation and density rather than Ms. Carroll directly communicating the information to her students. When further probed about her understanding of the order of instruction as related to the 4E x 2 model, she stated, "[the] engage section will have students looking for evidence of connections

among the shapes; [the] explore section will look at convection current and plate boundaries." In the first reflective dialogue held five days after the introductory interview, Ms. Carroll was asked to explain her rationale for on her approach to designing instruction for a unit on Earth's layers. She continued to articulate a held conception regarding the order of instruction. She stated "…the 4E x 2 is the gold medal standard for [lesson planning]" and "[the model] helps me think about how I plan that lesson differently now."

However, when Ms. Carroll was observed teaching one of the lessons from this unit on Earth's layers, she began the lesson by asking rapid-fire questions designed to the have the students recall information from the previous lesson's lecture. This instructional decision did not allow for active engagement of all students at the start of the lesson. Rather only those students who chose to participate in the instructional activity were engaged in the lesson; the other students were not. Here is a sample of the rapid-fire questions Ms. Carroll asked her students:

> What can you tell me about the Earth's crust? Don't look at your notes. What is different about the oceanic and continental crust? What are shadow zones? Where are they coming from initially? When can [scientists] observe them? When an earthquake occurs, where do they go? (Carroll, observed lesson, February 22, 2013).

In this example, her articulated conception about the order of instruction as defined within the 4E x 2 model did not align with her observed practice. In this lesson, Ms. Carroll used teacher-centered instructional methods as she constructed explanations for how the properties of Earth's layers impacted the movement of tectonic plates and did not engage the students nor did she provide an opportunity for exploration.

However, Ms. Carroll continued to hold this conception and referenced the use of the 4E x 2 model when asked to reflect on her mindset to instructional planning in subsequent dialogues. As she described her plans for the first lesson in an upcoming instructional unit on the rock cycle, she stated:

> Students will group the rock samples according to how they thought they would be grouped together based on looks. Then [students] read an article about rocks taken from a website; gives [them] information about three types of rocks. After they read, they could re-arrange why they grouped [the rocks] initially and then tell why they made any changes to their grouping after they have read the article. (Carroll, dialogue, April 24, 2013).

When she was observed teaching this lesson designed to introduce the rock cycle, Ms. Carroll did utilize the format she described in the dialogue above. She began the lesson by having students brainstorm responses to the following questions, which served to engage her students in the lesson:

1. How many types of rocks do you think there are?
2. Name as many types as possible.
3. Can you think of a way in which a rock is created?
4. How would a rock change its type?

In the next segment of the lesson, each pair of students were given a tray containing ten rock specimens. Students were then asked to "group the rocks and explain why [they] grouped the specimens in that way." This instructional activity directed students to explore the ideas they had brainstormed during the previous segment of the lesson. In the next lesson within this instructional unit, she had her students explore various rock samples before Ms. Carroll presented relevant content on the three types of rocks and phases of the rock cycle. In this activity, students were observed rotating among various stations within the room displaying a group of similar rock samples. At each station,

students recorded their observations about the rock samples and developed ideas on how the samples could have been formed using the information they had learned in the previous lesson. At the conclusion of the investigation, students entered into a whole-class discussion regarding their findings. Ms. Carroll recorded the students' responses as they reported their observations. Then, she asked students to identify common words from the description of each station. Finally, she tied these terms to each type of rock displayed at the various stations. By using this format, Ms. Carroll engaged her students in an exploration of the concept before she facilitated the development of the students' understanding of the specific terms. Utilizing this practice aligned with Ms. Carroll's held conceptions regarding the order of instruction within effective inquiry-based practice.

Ms. Carroll continued to articulate this held conception throughout the remainder of the study. In a reflective dialogue at the end of the study, she described her plans for an upcoming lesson on natural selection. She commented:

> I am thinking about having them look at the data first and talk about what they notice about the data. Then, describe what time period they think it is and have them come up with an explanation that something had to change in their environment. Let them come up with the explanation first, then tell them what time period it is and then see if they can come up with it. Then, [show the video] after the fact they had decided that environmental factors were influencing these changes in the moths. (Carroll, dialogue, May 2, 2013).

In reflecting on her approach to designing this lesson plan, Ms. Carroll stated that she began the lesson by engaging her students with having them make observations of presented data rather her explaining the trends and patterns first. She continued to reference the 4E x 2 model as she described how she included an opportunity for her students to explore those ideas and develop an explanation before she provided any

content information. When asked to articulate why she continued to utilize this approach, Ms. Carroll reflected, "The 'explore before explain' makes it more meaningful to [the students] because they are having to think about it rather than me saying it to them."

Conception #2-Teacher as facilitator. Within the interviews and reflective dialogues, Ms. Carroll expressed a held conception that aligned with developing and proficient inquiry-based practices about facilitating instruction. As stated within the instruction construct of EQUIP, proficient implementation of inquiry includes having the teacher facilitate learning rather than being at the center of instruction.

In the introductory interview, Ms. Carroll was asked to reflect on any changes she had made "in moving [her] instruction to more inquiry-based." She commented on recognizing the need "to give [students] the opportunity to find the information instead of being so willing to give it to them." In subsequent reflective dialogues, Ms. Carroll continually referenced her conception of needing to transition from teacher as a provider of knowledge to a facilitator of student learning. During a reflective dialogue that took place approximately midway through the study, she reflected on the implementation of a learning station activity within a unit on the rock cycle. She noted that students were confused and unable to identify the type of rock for each sample. She reflected:

> I should have labeled the rock [samples] with the name of the rock and the type. [The students] would still have to noodle it though and think about [how each type of rock was formed]. They are applying what they know about how each rock forms. (Carroll, dialogue, April 12, 2013).

Her comments indicate she is cognizant of providing support for student learning in order to allow them to explore the concepts and develop their own explanations.

When asked to reflect on what enabled her to make this transition from teacher of provider of knowledge to teacher as facilitator, Ms. Carroll was able to identify specific transformation points she had when employing this approach. She elaborated that she had to work with the students to "keep them from blurting out just anything" and help them learn to "carefully consider their answer" before responding. She also commented that she perceived her students were frustrated when she refused to give them the answer and encouraged them to find the evidence to support their ideas. She stated, "They want confirmation whether they are right or not."

This conception continued to be expressed in one of the final dialogues when Ms. Carroll reflected on how the students performed on a task to sort pictures of various organisms in order in which they first appeared on Earth. She was able to recognize this frustration within her students, and how she adapted her approach to address it. She stated:

> The students did not like having to glue the pictures [in their notebooks]; it was too permanent for them without knowing if they were right or not. Once they glued the pictures, they felt like they could not make changes and would be penalized. So, in my next class, I told [the students] it was okay to be wrong; that we would go back and make changes. (Carroll, dialogue, May 2, 2013).

She further commented that when she first started using the strategies advocated by the professional development initiative, she recognized that her students were not used to having to construct understanding for themselves and that she had to adjust her approach to planning and instruction. She stated:

> [Using this approach] is time consuming in the preparation because you want to think it through…. You are never sure what the outcome is going to be. You can have questions in line…but when you ask question A, you don't even get the response you were expecting from A, then you have to be willing to go back. If

> you are not willing to monitor and truly adjust as needed, then it's not any different really because you have not allowed for the time necessary the kids require. (Carroll, interview, February 18, 2013).

In addition to reflecting upon the role of the teacher as facilitator, Ms. Carroll commented on her use of asking students to provide evidence in support of their responses in order to strengthen their understanding. In the introductory interview, she commented:

> I've tried to focus on having students use evidence all year long. This is something really important about science that I want them to know; science is constantly changing; finding new things. I tell them this is the best explanation science has now based on the evidence. When new evidence comes to light, things may change. For example, I asked them how scientists know that fish came before reptiles. The students mentioned that we could look in the rock layers for evidence. (Carroll, interview, February 18, 2013).

She further commented on her plans to incorporate this strategy. She reflected that she intentionally asked students to develop explanations for how scientists have theorized the structure of Earth's interior using information about the thickness, temperature, and composition of the various layers. In a subsequent dialogue, she spoke about how she had been very purposeful in asking students to provide a justification for their response. Ms. Carroll continued to hold this conception as evidenced in her final reflective dialogue. She commented that she was planning for students to watch a video depicting various environmental issues and to select one of those issues on which to conduct further research as a culminating project for the year. She stated, "the video gave numerous solutions about each of the issues and that she would expect students to provide evidence for their justifications as to which of the solutions they selected as the best."

Ms. Carroll also noted in the introductory interview that she wanted to address her use of classroom discourse in her role of facilitator. She commented, "questioning leads to critical thinking. If you can get your questions at a higher level, [students] get accustomed to thinking about things at a higher level." However, during observations, Ms. Carroll continued to ask recall level questions utilizing a rapid-fire approach. Her articulated conception did not align with her instructional practice. In an observed lesson, she displayed a diagram of the rock cycle and asked the following questions to the whole class without calling on specific students:

1. What kind of rock is made when [weathering, melting, pressure etc.] happens?
2. When lava cools and hardens, what happens?
3. If the rock melts, what happens?
4. Are erosion and deposition happening [at this point]? (Carroll, observed lesson, April 19, 2013.)

She was observed implementing this method of asking questions in another observed lesson. Students were asked multiple rapid-fire questions about the divisions within the geologic time scale. As with the previous observed lesson on the rock cycle, questions were directed at the whole class rather than calling on specific students.

Throughout the study, Ms. Carroll did indicate that she struggled with questioning in that she had reservations about giving too much information when she asked questions of her students. She also expressed being unsure of what to do when students gave unexpected answers in terms of how to ask a follow-up question while maintaining focus on the topic. These ideas were expressed in the post-study interview when she was asked to reflect how she had changed in her approach to discourse. She stated:

> "I sought to ask more thought-provoking questions and be more intentional in my approach. I had to practice using this format or methodology. It was a natural

> progression for me as my confidence level increased. I felt effective in giving [students] feedback and rewording questions for clarity."(Carroll, interview, June 24, 2013).

Conception #3-Formative assessment. Within the interviews and reflective dialogues, Ms. Carroll expressed held conceptions that aligned at the developing level about the use of assessment. However, as the study progressed, Ms. Carroll began to express changes in regards to her conceptions about assessment, and these expressed concpetions aligned with a proficient level of implementation. As stated within the assessment construct of EQUIP, proficient implementation of inquiry includes practices designed to evaluate student prior knowledge and utilize these findings to adjust instruction. In addition, this construct looks at practices used to promote process-focused activities that utilize factual and authentic measures and having learning facilitated by the teacher rather than being at the center of instruction.

In the introductory interview, Ms. Carroll stated that prior to the start of her involvement with the professional development initiative she was unaware that "assessment could take place throughout an instructional unit or be used to inform one's instruction." Rather, she viewed assessment as solely summative measures that occurred at the end of a unit. She also stated that she viewed only quizzes and tests as assessment measures and did not see instructional activities such as questioning or brainstorming as forms of assessment.

When Ms. Carroll was asked to reflect on how she planned to incorporate formative assessment within an instructional unit on the rock cycle, she commented that she had planned to have students "fill in a diagram of the rock cycle without the

processes labeled as a formative assessment." However, when she was observed implementing this instructional activity, she had the students complete the diagram as a homework assignment the previous night. Then, during the lesson, she reviewed the answers with the students in a whole classroom setting as the diagram of the rock cycle was displayed. In going over the diagram with the students, she asked questions to the class as a group rather than checking in with each student regarding his/her understanding of the concepts. After the lesson, when asked to reflective on having students label the diagram of the rock cycle as an effective assessment of understanding, Ms. Carroll replied, "They either got it or not." She was basing this assessment on the responses she received from asking questions to the class in general rather than calling on individual students-either on an individual basis or having them participate in a response system. Therefore, her conception about how to effectively utilize formative assessment did not align with implementation within her practice.

In reflecting on the scope and sequence of the final instructional unit of the semester, Ms. Carroll again remarked that she intended to begin the unit with a formative assessment probe. She planned to first give students a graph showing the change in peppered moth populations over time. They would record their observations and inferences about the data and then develop an explanation for the change. Then, she would show students a brief video clip about the phenomenon of the peppered moth having to adapt to changes in its environment both during and after the Industrial Revolution. She remarked, "[I want to] see if [the students] could figure out that something happened to the lighter-colored moths and the dark-colored survived." This

instructional activity would allow her to assess the students' prior knowledge and current understanding about natural selection and adaptions.

During the observation of this lesson, Ms. Carroll was able to more proficiently implement the formative assessment strategy. She distributed the graph showing the change over time in various peppered moth populations. She then asked the students to "make observations about the graph itself. She further reminded students to "pay attention to the axes and look for trends and patterns in the data." After a few minutes of working independently, she called upon individual students to share their observations. Then, she instructed the students to share their explanations with a partner about "why the moth populations changed." Again, after a few minutes, she called on individual students to share the explanations discussed with his/her partner. She was more intentional in calling on individual students and noting their responses than in previously observed lessons.

Ms. Carroll was asked to reflect on her design and use of the phenomenon of the peppered moth as a formative assessment on students' understanding of adaptations. She commented:

> [Today] we talked about adaptations and what they do for an organism. [The students] told me that an adaptation is 'something that allows an organism to survive.' They get that now, I see. I then asked them what if the environment changes and [the students] talked about 'if the adaptation is not present then the animal dies.' Then, I showed them a video clip on predators. And, [the students] linked predators and the effects on population and environments. (Carroll, dialogue, May, 16, 2013).

At this point, she was starting to demonstrate an alignment of her held conceptions about formative assessment and implementation within her practice. She

continued to articulate this conception in the post-study interview. When asked to reflect on the changes made to her approach to utilizing assessment, she responded:

> I understand that to be effective, I have to check in with every student during the lesson. Then, I need to analyze that assessment data to figure out how my students are interpreting the information. (Carroll, interview, June 24, 2013).

Conception #4-Content depth. Within the interviews and reflective dialogues, Ms. Carroll expressed held conceptions that aligned with developing and proficient levels about the design of instruction. As stated within the curriculum construct of EQUIP, proficient implementation of inquiry includes lessons that provide depth of content with some significant connections to big ideas and incorporate student investigations that link well with content.

In the introductory interview, Ms. Carroll described her approach to inquiry-based practice as "one in which [the teacher] has to intentionally organize student learning to enable students to gain an understanding of those big ideas as well as uncover and address misconceptions." She stated:

> I try to tell [my students] they compartmentalize the information from unit to unit. Like in the force and motion unit, they did not bring anything from there into what we talked about with gravity and tides. So, when I ask those higher-level questions like 'With this position and the ESM arrangement, what type of tide or phase of the moon or eclipse is happening?' they don't see that can happen all together. They struggle with the big picture and be lead there. (Carroll, interview, February 18, 2013).

Within subsequent dialogues, she continued to describe a held conception about identifying the big ideas within a unit of study and how student learning of those big ideas helped them develop conceptual understanding rather than just knowledge of factual information. As evidenced in her reflections upon on planning a unit on the layers

of the Earth, she stated, "[I] decided to start by teaching layers of the Earth first to serve as the anchor point for the unit." She further described her rationale for starting her students' study of Earth's geologic processes with the layers of the Earth rather than with the study of plate boundaries or seismic waves as this concept was a "source of misconception because we cannot see into the interior of Earth." She commented that she had noted that students needed to address this misconception before moving onto the study of plate movement and seismic waves. In a subsequent dialogue, she was asked to reflect on her approach to planning a unit on minerals. Her comments indicated a held conception regarding the importance of identifying conceptual knowledge students needed to learn rather than only the factual knowledge. She stated:

> My concerns with [the unit on] minerals are with students understanding that [minerals] make up rocks and the characteristics that determine a substance to be a mineral are not the same things as the properties of minerals…However the standards say that [students] need to understand that minerals have properties that make them useful. But, I feel like [students] have to understand what [those] properties are. It is foundational information students need...(Carroll, dialogue, April 12, 2013).

In a subsequent dialogue, she again demonstrated the held conception as she reflected on how student misconceptions were interfering with student learning during a lesson on geologic time and evolution. She commented:

> Students just think various animal species just appear rather than having evolved from more primitive organisms. When we talk about geologic time, I will say 'mammals first appeared in this time period' and students think we snap our fingers and the mammals just appear. (Carroll, dialogue, May 2, 2013).

In a dialogue towards the end of the study, she described her plan for implementing an investigation at the start of the unit on fossils to provide students with a connection to the bigger idea of change over time. She had students examine a set of pictures depicting

various animals and put them in order in which the students thought they first appeared on Earth. The set of pictures included extinct animals such as trilobites and wooly mammoths as well as currently living species such as alligators and birds. She commented that as students began to sort the pictures, she was initially shocked by the high level of interest students were displaying about this topic. She noted, "[The students] have not been as resistant to studying this topic as students have been in years past."

As evidenced through her comments in the various dialogues, Ms. Carroll was able to express her understanding of how adolescent learners can typically struggle with obtaining in-depth understanding of these concepts as they are more abstract concepts or cannot be directly observed. She also commented on how students tend to compartmentalize information learned within a unit and not be able to connect the concepts to other units of study. She stated:

> They struggle with the big picture. They can see things individually but putting it together seems difficult for them. Like in the force and motion unit, they did not bring anything from there into what we talked about with gravity and tides. Even within a unit, they compartmentalize. When they learned about moon phases, they did not pull that information into [their explanations of] eclipses and tides. (Carroll, interview, June 24, 2013).

Held Misconceptions

Misconception #1-Student motivation. Beginning with the interview conducted at the start of the study, Ms. Carroll frequently expressed comments regarding a lack of student motivation, especially as she compared the students in her gifted and talented science classes (G/T) and students in her grade level (regular ed) science classes. She was asked to reflect on the impact of this concept on overall student understanding and

achievement she had noted during the course of her involvement with the professional development initiative. She commented:

> With inquiry, [the students] are more engaged for the most part. A lot of it has to do with their personal motivation. It does seem to work easier with the G/T kids…This group of kids in general do not want to work. Most of my regular ed kids do not take any time out of class to prepare for science. They do not do any work outside of class. (Carroll, interview, February 18, 2013).

Her misconception regarding student motivation among students in her G/T classes and her grade-level classes were referenced again in the introductory interview conducted at the start of the study as she stated:

> [G/T] kids will get the work done whether they have to do it at home or not. My regular ed kids-education is not a priority for them. As far as getting something done, this isn't important. (Carroll, interview, February 18, 2013).

This misconception was further reinforced as she described how students were progressing in working on an assignment about Earth's layers:

> Technically, they've really had time in class to get it done if they worked hard and got it done. Some people don't use their time very well. And, I feel that in 8th grade, if I'm constantly on them about managing their time, they are never going to account for it themselves…at this stage, they have to learn to monitor their time well. Because if someone is always telling them, they will never learn to manage it themselves. (Carroll, interview, February 18, 2013).

In subsequent reflective dialogues, Ms. Carroll was asked to think about ways in which she could modify her instruction to address some the perceptions she identified regarding motivation and students in her grade-level classes. She commented on how she could design a graphic organizer for use with the students in grade-level classes during an investigation on the types of rocks and the processes within the rock cycle. During this instructional activity, students would be working in groups and rotating among various stations set up throughout the classroom to observe groups of rock specimens and record

their observations. When asked to reflect on how the implementation of this strategy impacted student learning, she commented on how students in the regular education class refused to engage in the lesson, were off-task and lacked self-control. She then stated, "They do not want to think. They demonstrate a lack of effort, which leaves me with three options for them: investigate, read, lecture." When asked to further reflect on her perceived rationale for the behaviors she noted from the students in her grade-level class, Ms. Carroll stated:

> When [the students] did an activity in stations, all classes were put in groups. The regular ed students were the least focused. They did not give a rip about figuring out how this rock [specimen] changed…They did not make a conscious effort to learn the material. (Carroll, dialogue, April 24, 2013).

Towards the end of the study, Ms. Carroll began to be more intentional about providing greater support for students in her grade-level classes. For example, she began providing outlines of notes so that students could have more focus during class lecture and discussion. In an observed lesson on geologic time within her grade-level class, she wrote an outline on the board listing the key points for each era. After students had the opportunity to copy the notes in their science notebooks, she engaged them in a discussion. When students appeared confused or unsure of their answers, she would remind them to "look on your notes; you have the information there." However, when her students did not respond in the way in which she expected, Ms. Carroll would revert to her previous practices. For example, when the majority of the students within her 7th period grade-level class did not complete a homework assignment to research and construct a diagram of Earth's layers, she became very frustrated and lectured the

students about their lack of effort and motivation. In turn, these students disconnected with her and were unwilling to actively participate within the reminder of the lesson.

However, when asked, Ms. Carroll was unable to identify any specific strategies she had used to address the noted lack of effort from the students. She did not mention if she modeled the strategy for the students or reminded students of expectations for behavior during interactive and/or group activities.

Misconception #2-Cognitive ability of students. Another misconception noted throughout reflective dialogues with Ms. Carroll involved her perceptions about student cognitive ability as compared to demonstrated behaviors within the classroom. Ms. Carroll consistently commented on the difference in abilities as expressed by students in her G/T classes as compared to the students in her grade-level classes. She stated, "switch[ing] gears [between G/T and reg ed classes] is hard. "I [teach] my regular ed and ask the same questions and sometimes I get blank stares; they are totally not understanding what I'm asking them." She frequently stated that she assigned the exact same work to the G/T classes as she did to the grade-level classes. She also used the same approaches with her questioning and discourse with both classes.

Ms. Carroll's conceptions regarding the differences in student motivation and cognitive ability impacted her ability to proficiently implement inquiry-based practice when engaging her students in classroom discourse. This conception was evidenced in classroom observations as the students in the G/T classes asked more questions and responded more rapidly to her line of rapid-fire questioning. However, most of the questions they asked within these class discussions were at the recall and understanding

levels. As noted in field notes, many of these questions were either asking for verification of given instructions or were off-topic. In addition, Ms. Carroll typically only called on the same three or four students in her G/T class as these were the only students who would actively engage in a classroom discussion. Yet, in grade-level classes, Ms. Carroll intentionally called on both volunteers and non-volunteers to answer questions. Therefore, a higher percentage of students were engaged in the discussion as compared to students in the G/T class. In a subsequent dialogue, she was asked to reflect on adjusting her instruction to plan for a differentiated approach to questioning. She commented, "I try to make [the grade-level students] wait but they want to blurt out." In an observation of her grade-level class following this dialogue, she purposefully asked students several times to "wait before you just shout out the answer."

During the dialogue sessions, Ms. Carroll frequently reflected on assessing student prior knowledge at the start of a unit. However, her comments revealed a misconception regarding the differing levels of prior knowledge and experiences students brought to her classroom. When asked to reflect on the amount or depth of prior knowledge her students had about a particular concept, she frequently commented on the difference between her G/T and on-grade level students. Her comments indicated a perception that G/T students brought higher levels of prior knowledge to the classroom. Ms. Carroll stated:

> They don't bring a lot of prior knowledge about the types of rocks. Most of the time, they could not come up the names of the types of rocks. On the pre-assessment, I asked them how many types of rocks there were. I got answers ranging from twenty to a million. A few students in my G/T class said 'three'. Otherwise, they said things like 'graphite.' There was an association, but they grasp at the words. (Carroll, dialogue, April 24, 2013).

When asked to further reflect about the levels of questions being asked by her G/T students, she commented:

> The kids that seem to have the better questions are the ones who watch Discovery or National Geographic-some of the education shows that some of the other kids don't even bother with. So, I think it's a matter of what they've been exposed to." (Carroll, interview, June 24, 2013).

> It is a hard transition for me to go from a [G/T] class that will interact with you and will process what you are saying and try to be responsive. Then, go to a class where they won't even look at you most of the time when you are talking to them. It makes me feel like they are not paying attention and they aren't. They do not focus on anything that's going on. They pick up on the strangest things. It's not anything that is your focus for the day. (Carroll, interview, June 24, 2013).

For example, during a lesson observed in both a G/T and a grade-level class, both groups of students demonstrated a similar lack of prior knowledge about the names of the three types of rocks as well as not being able to provide examples of the three types. From the transcript of the classroom observations, student responses within the G/T class about the types of rocks in existence were 100, 3, several, and a million. In comparison, the student responses in the grade level class were millions, 42, 5, and 100. Both groups of students gave responses that were accurate (3 and 5) and responses that were inaccurate (100, million, and 42). Within this lesson, students were then asked to name as many types of rocks as possible. Student responses in the G/T class included granite and graphite whereas the student responses in the grade-level class included pebble, granite, boulder, sandstone. Both groups of students were unable to name the correct group names (igneous, sedimentary, and metamorphic). Yet, Ms. Carroll perceived the grade-level students as having significantly less prior knowledge of the information and concluded the grade-level students were less willing to learn the material.

Assessing Levels of Implementation of Inquiry-based Practice

Observed instructional practice was assessed for levels of implementation within each of the four constructs of the EQUIP: instruction, discourse, assessment, and curriculum (Marshall, Horton, Smart, & Llewellyn, 2008) in order to measure consistent transformations in practice. Scores on the EQUIP provide evidence of sustained transformations of practice over time. Within EQUIP, the instruction construct examines the implementation of the 4E x 2 Instructional Model and the role of both student and teacher within the lesson. There are five factors within this construct. The discourse construct encompasses the components of effective questioning and classroom dialogue between teacher and student as well as among students. Utilizing questioning effectively involves asking higher level questions and asking students to provide a justification for their responses. There are five factors within this construct. The assessment construct encompasses practices designed to evaluate student prior knowledge and utilize these findings to adjust instruction. In addition, this construct looks at practices used to promote process-focused activities that utilize factual and authentic measures. There are five factors within this construct. The curriculum construct encompasses the components of lesson content and classroom investigations. There are four factors within this construct.

In Table 4.1, the overall EQUIP scores for each construct from each of the three observed lessons are reported for Ms. Carroll. As noted in the table, Ms. Carroll's scores ranged from pre-inquiry (level one) to proficient inquiry (level three) as the overall score for each construct prior to her participation in this study. The overall inconsistency of

these scores were not noted in other participants from the school. As evidenced in the pilot study, she was observed attempting to act as a facilitator for student learning although she frequently reverted to the role of instructor. Her lessons occasionally had students exploring a concept prior to receiving or researching the explanation of the content. She was not consistent in engaging her students in open-ended dialogues that involved students giving justifications for their responses.

During her participation in ongoing reflective dialogue as part of this study, Ms. Carroll's overall scores reflected a shift towards more consistent implementation of inquiry-based practice at the proficient level. Her overall scores for each construct moved from being inconsistent-varying between the pre-inquiry (level one) and proficient (level three). Throughout the study, Ms. Carroll scored consistently above the pre-inquiry level, with seven out of the twelve overall scores at the proficient level.

Study participant #1- Ms. Carroll	Pre-study score range	Observation 1	Observation 2	Observation 3
Instruction	1-3	3	2	3
Discourse	2-3	2	3	3
Assessment	2-3	2	2	3
Curriculum	1-3	3	2	3

Table 4.1: Overall EQUIP Scores for Study Participant #1-Ms. Carroll

Table 4.2 presents the individual scores for each factor within the four constructs of EQUIP. In the evaluation of Ms. Carroll's scores, she scored consistently at the developing (level two) and proficient (level three) stages of implementation. Out of 57 possible scores, Ms. Carroll had 23 scores at the developing level and 32 at the proficient level. These scores align with Ms. Carroll's transitions within her held conceptions about inquiry-based practices expressed in the reflective dialogues. As she progressed within the study, she was to articulate held conceptions that aligned with the observed levels of practice.

At the start of the study, Ms. Carroll scored at the pre-inquiry and developing inquiry levels for the instruction construct. In the three observed lessons, she scored more consistently at the developing and proficient levels of inquiry. Within the discourse construct prior to the start of the study, she scored at the developing and proficient inquiry levels. In the three observed lessons during the study, Ms. Carroll scored more consistently at the proficient level of inquiry indicating a more sustained transformation of practice.

Prior to the study, Ms. Carroll's EQUIP scores within the assessment construct ranged between developing and proficient levels of implementation. In the first two observed lessons during the study, Ms. Carroll's scores remained at the developing level. However, she scored at the proficient level in the third observed lesson indicating a slight shift towards implementation. Within the curriculum construct, her scores ranged from pre-inquiry to proficient level of implementation. In the three observed lessons during the

study, Ms. Carroll scored primarily at the proficient level indicating a more consistent level of implementation.

Construct	*Factors*	*Observation #1*	*Observation #2*	*Observation #3*
Instruction	Instructional strategies	3	2	3
	Order of instruction	2	3	2
	Teacher role	3	2	3
	Student role	3	2	3
	Knowledge acquisition	3	2	3
Discourse	Questioning level	2	3	3
	Complexity of questions	2	3	3
	Questioning ecology	3	3	3
	Communicatio n pattern	2	2	3
	Classroom interactions	2	3	3
Assessment	Prior knowledge	2	3	3
	Conceptual development	3	2	3
	Student reflection	2	2	2
	Assessment type	3	2	3
	Role of assessing	2	2	2
Curriculum	Content depth	3	3	4
	Learner centrality	3	2	4
	Standards	3	3	3
	Organizing and recording information	2	2	3

Table 4.2: EQUIP Scores by factor for Study Participant #1-Ms. Carroll

Study Participant #2-Ms. Newman

Ms. Newman taught two classes of 6th grade and three classes of 7th grade gifted and talented science. In each of these classes, students were homogeneously grouped; however, the students did vary by readiness and learning profile. From the analysis of the data, Ms. Newman demonstrated a strong understanding of the concepts of inquiry-based instruction as presented within the 4E x 2 model. However, these understandings were not translated within her observed instructional practice. There appeared to be a lack of connection between her conceptions and her implementation.

Held Conceptions and Representations within Instructional Practice

Analysis of the data from the interviews, reflective dialogues, and, classroom observation looked for evidence of held conceptions about effective inquiry-based practice as defined by the 4E x 2 Instructional Model. For Ms. Newman, held conceptions and misconceptions were articulated within the interviews and dialogues. In addition to participating in reoccurring reflective dialogues, Ms. Newman was formally observed three times each during classroom instruction for evidence of identified conceptions and misconceptions within her practice. Observed classroom lessons were evaluated for evidence of the implementation of those held conceptions. Lessons were also evaluated for evidence of how the identified misconceptions were impacting the effective implementation of inquiry-based practices.

Conception #1-Order of instruction. Within the interviews and reflective dialogues, Ms. Newman expressed held conceptions about planning for instruction that aligned with proficient inquiry-based practices. As stated within the instruction construct

of EQUIP, proficient implementation of inquiry includes sequencing instruction to engage students in investigations that allow for an exploration of the concepts before receiving the explanation. However, throughout the study, Ms. Newman was observed inconsistently implementing inquiry-based methods within her practice. She regularly lectured and provided the explanation for concepts before students were given the opportunity to explore their ideas. Even though she purposefully designed lessons using the 4E x 2 model, she would modify the lesson upon implementation and omit opportunities for students to explore concepts and ideas within her lessons. These modifications were especially observed in lessons that were taught towards the end of the school year. In the final reflective dialogue, she remarked that she felt more pressure to "cover all of the material."

In the pre-study interview Ms. Newman articulated an understanding that students needed to explore concepts before either receiving or constructing the explanation. She commented:

> This is my third year of inquiry…Almost all of my lesson plans follow the 4e x 2 model and I find that writing and implementing these plans takes much less time. I want to [teach] in an inquiry-based way. I could give them the PowerPoint notes, give them a worksheet, and say the test is next week. I could do that all day. I know that's not the best way to do it. That's my challenge at this point. (Newman, interview, March 11, 2013).

Ms. Newman continued to hold this conception as participated in the reflective dialogues. In the fourth dialogue, she articulated a held conception of designing instruction giving students opportunities to explore concepts before receiving the explanation. When describing a lesson plan she developed on food chains and food webs, Ms. Newman commented:

> For the engage, students will draw a simple food chain and then work together in small groups to make a food web from those food chains for the explore. For the explain, go back and look at everyone's web and see if everyone used the right terms such as producer or consumer. (Newman, dialogue, April 22, 2013).

She further commented on this lesson as she stated, "This is the first time I've done these activities as an engage; I usually do these [types of] activities at the end." She also describe how she was utilizing headings for engage, explore, explain, and extend when writing her instructional strategies for each lesson.

However, during the classroom observation of this lesson, she implemented the lesson with a teacher-centered focus. The lesson began with students listing all of the foods they had consumed within a 24 hour period. Then, students developed a simple food chain to trace the origin for each of the foods. At this point in the lesson, however, Ms. Newman added a brief visual presentation on key terms such as producer, consumer, and decomposer, thereby giving students the content before they were engaged in the lesson or had the opportunity to explore their ideas regarding the origins of the food the students had consumed. When asked to reflect on her decision to modify the lesson from what she had originally prepared, she stated, "I decided [the students] needed to know the terms first."

In the following dialogue, Ms. Newman continued to articulate this conception as she described instructional plans she had written for a lesson on soil, which was a topic in her overall unit on ecosystems. She noted:

> For the engage, give students three different types of soil to observe. Then, for the explore, we go out and dig up soil to compare the soil horizons from the different areas. Then, I have [students] perform soil percolation tests. (Newman, dialogue, April 29, 2013).

However, when asked to reflect on this lesson and the unit on ecosystems overall, Ms. Newman stated:

> I spent little time on soil and very little time on water. [The students] had studied renewable and nonrenewable resources in social studies, so we just reviewed real quick. They had shared with me what they had learned and I just had to throw in a few things. (Newman, dialogue, May 20, 2013).

She further reflected:

> Because of time, we had to rush through the [soil percolation tests.] So, I gave them an outline giving them the materials they would be using and filling in the blanks for the procedure. It wasn't exactly cookie-cutter, but [the inquiry-based activity] was guided. (Newman, dialogue, May 20, 2013).

In another reflective dialogue, Ms. Newman described a lesson she had developed to introduce a unit on minerals. First, she would have her students make observations of mineral samples and describe how they would group the samples, which served as the engage for the lesson. Then, she planned for the students to match their descriptions to pictures of various groups of minerals. However, during the observed lesson, instead of allowing students the opportunities to further explore these concepts, she moved into a PowerPoint and provided the explanation for the unique characteristics of minerals. Furthermore, she showed an interactive video at the conclusion of lesson rather having students brainstorm their ideas about the uses of minerals as she had planned in the lesson plan reviewed in the dialogue.

In reflecting on an upcoming lesson on fossils within this same instructional unit, Ms. Newman described the lesson plan as having students examine fossils specimens and describe how they thought each fossil formed to engage them in the lesson. Then, she planned to have the students look at an illustrated geologic time scale in their science

texts. Students would then be asked to match up the specimens with other similar organisms depicted on the visual to provide students the opportunity to explore the concept. However, in observing this lesson, Ms. Newman did not have the students compare the specimens to the illustrated geologic time scale, Instead, she moved directly into the explain phase as she showed a PowerPoint from which students took notes. To conclude the lesson, she led a whole class discussion asking students to share their ideas about how the fossils were formed. Again, she did not give students an opportunity to explore their ideas before she provided the explanation on how fossils are formed. When asked to reflect on her decision to alter the lesson from her written plan that followed the 4E x 2 model, Ms. Newman stated:

> I promised my students we would make fossils using plaster of Paris. They take the clay and make the mold with a plastic seashell. It takes about one whole class period to make the fossils. So, I had to finish [the planned lesson] in one day. (Newman, dialogue, May 15, 2013).

In the post-study interview, Ms Newman continued to articulate the conception that she was proficiently implementing an order of instruction as depicted within the 4E x 2. She commented:

> I look at lesson planning in a new way. I know I have to teach students to think. At the start of the lesson, engage students and then plan for an explore. 4E [x2 model] is second nature to me now. (Newman, interview, June 26, 2013).

However, Ms. Newman was unable to demonstrate a proficient level of implementation of this held conception about the order of instruction within her observed instructional practice.

Conception #2-Teacher as facilitator. Within the interviews and reflective dialogues, Ms. Newman expressed some inconsistently held conceptions regarding this

construct. As stated within the instruction construct of EQUIP, proficient implementation of inquiry includes having the teacher facilitate learning rather than being at the center of instruction. During the pre-study interview, Ms. Newman stated:

> discourse is an area that I wanted to work on this year. I found that the best way to ensure good discourse regularly was to include probing questions in my lesson plans and have questions readily available while teaching my classes. (Newman, interview, March 11, 2013).

Although she frequently engaged students in discussion, Ms. Newman was not consistent in her use of questioning to probe students for justifications for their responses at the start of the study. In her first observed lesson, an introduction to the muscular system, students were asked to squeeze a clothespin as many times as possible within a 60 second time period and record the result in their notebooks. Students were then asked to describe how their fingers felt. However, students were not asked to record their ideas as to why they were experiencing muscle fatigue or how other body systems were involved during the activity.

As Ms. Newman was asked to reflect on her transition from teacher as a provider of knowledge to a facilitator of student learning, she expressed conceptions that were inconsistent. For example, when describing her plans for a lesson to introduce the layers of the Earth, Ms. Newman commented:

> This afternoon, we are starting out with a density demonstration, and I ask students to predict what is going to happen. Then, the PowerPoint notes, which is the discussion about how scientists gather information about Earth's interior and notes on the layers. Students then copy six questions from the board; they are right out of the book (Newman, dialogue, March 11, 2013).

She further reflected, "I don't know how inquiry that is." She acknowledged that this approach did not support inquiry-based practice but she did not alter her practice to make

this a more student centered activity. This conception was evidenced again when she reflected on planning for an upcoming unit on plate boundaries. In describing a lesson plan she devised for having students identify the location of plate boundaries and the relationship of those boundaries to seismic activity, Ms. Newman noted:

> I could show students different maps showing the locations of volcanoes and earthquakes and demonstrate convection currents with the rheoscopic fluid…have students complete the Earth's layers chart but instead of doing the whole drawing and sketch, just have them talk about it and go into seismic waves. (Newman, dialogue, March 18, 2013).

In using this approach, Ms. Newman again utilized a teacher-centered activity, a demonstration, to present content rather than having students investigate the concepts and begin to construct their own understandings.

However, in the post-study interview, Ms. Newman continued to articulate a held conception that she was proficiently facilitating inquiry-based instruction. She commented:

> I make my lessons more student-centered and ask probing questions. I make sure I check-in with all students and give them feedback. I also realize that I do not have to always use labs to implement inquiry. (Newman, interview, June 26, 2013).

As evidenced in her comments, Ms. Newman held a correct conception about inquiry-based instruction. Yet, she was unable to translation this understanding into her instructional practice. She was observed implementing teacher-centered practices and providing the explanation of concepts rather than allowing students to explore their ideas and construct their own understandings.

Conception #3-Formative assessment. As stated within the assessment construct of EQUIP, proficient implementation of inquiry includes practices designed to evaluate

student prior knowledge and utilize these findings to adjust instruction. In addition, this construct looks at practices used to promote process-focused activities that utilize factual and authentic measures and having learning facilitated by the teacher rather than being at the center of instruction.

Within the study, Ms. Newman consistently reflected on how she uncovered student prior knowledge as well as the degree to which those conceptions were impacting student understanding of the concepts. For example, in a lesson introducing the rock cycle, students were asked to observe samples of rocks and group them according to noted characteristics. In reflecting on the lesson, Ms. Newman commented, "They knew the names of the three types of rocks. Students bring a great deal of prior knowledge; they get a lot of this in elementary school and it's something they can relate to." Following a lesson on energy pyramids, she reflected that students lacked the needed prior knowledge to complete the lesson as initially written. She commented that without that prior knowledge, students needed more guided practice before they could express their understanding of what the model represented. She stated:

> As far what the squares represented [the energy pyramid], they needed a good deal of guidance. The questions I planned for Engage were moved to the end of the lesson because students did not appear to have the prior knowledge to answer them. When, it didn't go well with [the first class], I decided to flip things and it seemed to go better. (Newman, dialogue, April 22, 2013).

Ms. Newman also referenced the impact of assessing prior knowledge on student understanding. At the conclusion of a lesson designed to introduce the geologic time scale, students were asked to list 15-20 major life events and depict them on a timeline. In her reflection, Ms. Newman noted, "Students are struggling with the timeline assignment.

They have a lack of prior knowledge about life events. Only one student was able to list actual dates [in years] for each event." She further stated that students had difficulty placing a time or an age in years on an event as they were unaccustomed to having to think about their life events in this way. She commented that she discovered she needed to help students find a point of reference for certain events by asking them to think about if they had an experience "before or after they started elementary school or middle school." She also noted that students had difficulty distinguishing key events such as the first day of school from other events such as going over to a friend's house.

Towards the end of the study, Ms. Newman begin to purposefully include opportunities to assess student understanding by asking questions at the start of the lesson to uncover prior knowledge or at the conclusion of the lesson to indicate understanding. During her third observed lesson, at the conclusion of a lesson on biotic and abiotic factors within an ecosystem, she asked students the following questions in order for them to demonstrate their understanding of the concepts presented in the lesson:

1. Where would be a good place to catch trout in this area [where they lived]?
2. What were the limiting factors in this activity?
3. What does having too much algae do [within this ecosystem]?

As the study progressed, Ms. Newman remained consistent in her held conceptions. Ms. Newman's use of assessment typically focused on quizzes and tests rather than formative assessments. In addition, most of these assessments were prescribed with few opportunities for student flexibility in demonstrating mastery of the content. Even when she chose to implement project-based assessments, the expected student outcomes were more product-focused such as creating a model of a eukaryotic cell or

developing a booklet containing information about an animal species. These assessments served more as verification of factual mastery rather than conceptual understanding. In the post-study interview, she further reflected that she used this same approach as in previous years. She stated:

> It's about the same. Maybe use different types and definitely use more check-ins. I realize how important that is. It has to be in my lesson plans." I have always used a variety of assessment techniques but 'checking in' with every student on a regular basis has not always occurred. I found that like with discourse, I must plan for regular informal assessments…For me, this is the only way to ensure that I regularly monitor the progress of every student and not just the ones who raise their hands. (Newman, interview, June 4, 2013).

Conception #4-Content depth. Within the interviews and reflective dialogues, Ms. Newman was able to demonstrate an understanding of identifying the big ideas within the content. As stated within the curriculum construct of EQUIP, proficient implementation of inquiry includes lessons that provide depth of content with some significant connections to big ideas and incorporate student investigations that linkwell with content. While reflecting on her thoughts about planning lessons and units, she did focus on the big ideas within content standards as well as plan instruction more conceptually with less focus on factual information. She stated, "I like to start my study of animals with invertebrates and go from least to most complex." When asked to reflect on the major concepts within an upcoming unit on ecology, Ms. Newman was able to identify several major themes within this unit: levels of organization, flow of energy within ecosystems, natural hazards and impact on the environment. She reflected, "The concepts in the ecology standard are not connected. I was thinking to focus on the ones

[the students] might not know first-soil, groundwater, and renewable and nonrenewable resources."

Ms. Newman also stated during reflective dialogues that she had intentionally planned instructional activities designed to further student conceptual understanding. However, at the start of the study, Ms. Newman typically engaged students in a variety of hands-on investigations that were designed for verification of understanding rather than building conceptual understanding. For example, during a unit on human body systems, students participated in a series of lab activities to measure reaction rate, pulse rate, and vital capacity. Within each of these activities, students followed a pre-determined set of instructions to collect data that supported an anticipated result (i. e. students exercised for a set amount of time and collected data that showed a rise in heart rate). During the first reflective dialogue, Ms. Newman acknowledged the importance of having students build conceptual understanding. She commented, "I am concerned if they are making the connections on how the body systems work together." However, the series of student investigations she designed focused on discrete systems without having students explore how body systems were interdependent. The systems were taught in isolation thereby not leading students to a deeper understanding of the concept of a closed system. Ms. Newman was observed continually implementing activities in which students were asked to verify content rather than explore the concepts.

Although Ms. Newman expressed concerns about having enough time to present the amount of content contained in the mandated curriculum, she frequently implemented instructional practices that emphasized students learning a quantity of knowledge rather

than exploring key concepts. In implementing a lesson on soil quality, she purposefully transformed a student-designed investigation into a teacher-centered activity. This action was most likely in response to wanting to move quickly through the curriculum. Ms. Newman commented:

> In the past, I've had students design their own investigations for a soil lab. Because of time, we had to rush through it. So, I gave them an outline giving them materials they would be using and filling in the blanks for the procedure. In the past, students have been given the whole day to design their investigation. They could bring in materials from home to use. (Newman, dialogue, April 29, 2013).

Ms. Newman also focused student learning at a recall or understanding level within her lessons. Students were often given worksheets from the textbook ancillary materials to complete. These worksheets focused on reviewing vocabulary or having students label diagrams. In addition, she did not plan instruction to challenge students beyond the minimum standards. She described a research project she had used in previous years during the unit on ecology in which students identified and researched a local issue in which populations were being threatened or disappearing. Within the constraints of the fast-paced curriculum, Ms. Newman did not choose to have students complete this project. Instead, she gave students "a couple of worksheets to go over for [learning the] vocabulary." Yet, having students complete this project would have challenged them to learn and apply the concepts from that unit.

In her instructional plans for an upcoming unit on invertebrates, she had listed activities such as comparing a natural sponge to a manufactured sponge and cutting out a pattern of a starfish. Listed among the activities in a different unit, she planned to have her students make a model of a fossil. When asked to explain her reasoning for

implementing this activity, she commented, “I promised my kids we would make fossils using plaster of Paris. They take the clay and make the model with a plastic seashell. It takes about one whole class period to make the fossils.” This instructional decision was based upon the desire to entertain students rather than build their conceptual understanding.

In subsequent dialogues, Ms. Newman ‘s reflections indicated her reverting to transmitting knowledge and encouraging student mastery of facts without much focus on understanding of content. Her focus became centered on teacher-directed instructional activities rather than student-centered activities that would develop conceptual understanding. When asked how she would plan for instruction within the unit on ecology, she listed several activities that were teacher-centered in order to convey content to students. She stated:

> We just saw a video about the Japan earthquake and tsunami so I may bring that back up and briefly mention how it impacted wildlife. I like to talk about limiting factors and do the Oh Deer activity. Then, I can cover renewable and nonrenewable resources when I teach rocks and minerals. (Newman, dialogue, April 15, 2013).

This conception was maintained as she reflected on an upcoming instructional unit on earth’s resources. She commented:

> I found a Gizmo [interactive simulation] on the Rock Cycle so that was my engage/explore. They have a good amount of prior knowledge of rocks. So, I have a good PowerPoint and plan to give them an outline to fill in the words. I will then pass around some examples of the various types of rocks: intrusive, extrusive, etc. while they take notes. (Newman, dialogue, May 15, 2013).

However, in the post-study interview, when asked to reflect on the advantages of the implementation of inquiry-based practice, she commented:

> [It] makes students thinkers and problem-solvers. It is a student-centered approach with the teacher facilitating the learning process. It gives students multiple opportunities to learn the material and make connections between the concepts. (Newman, interview, June 26, 2013).

She continued to articulate held conceptions in line with proficient implementation yet she did not express these held conceptions in reflecting upon lessons she was planning or she had taught.

Held Misconceptions of Inquiry-based Practice

In the analysis of the pre-study interview and subsequent reflective dialogues, responses were examined for evidence of currently held misconceptions about inquiry-based instruction. For Ms. Newman, two misconceptions were noted, especially within her reflections regarding her 7th grade classes for students who were identified as gifted and talented. These misconceptions could be linked back to currently held conceptions regarding the implementation of an accelerated or "fast-paced" curriculum and the emphasis of standardized testing.

Misconception #1-Accelerated curriculum. During this study, Ms. Newman was teaching under the auspices of a district-mandated, "fast-paced" science curriculum in which all of the 7th grade academic standards, most of the 8th grade academic standards and selected 9th grade physical science standards were incorporated into her instruction for the current year. The following school year, the teacher will incorporate the 8th grade force and motion standards with the 9th grade physical science standards into her instruction with the goals being for these gifted and talented students to receive high school credit for 9th grade physical science as 8th graders. However, these students will still be required to take district-mandated 8th grade science benchmark assessments AND

the state standardized science assessment at the end of the year. Therefore, she had to address the content/concepts within the 8th grade science standards during the 8th grade course so that students will be prepared for those assessments as well as obtain mastery for the 9th grade physical science standards.

Ms. Newman frequently reflected on the impact of having to follow this district-mandated curriculum. She noted:

> I think some of my kids have done well with [the fast-paced approach.] The one who need to be in it are doing very well because they make 100s on tests. They seem to be enjoying it and I have some in my first period class that are so smart and they are the ones who should be in it. They are the ones who are doing really well with it because we keep moving along. It's keeping them interested. (Newman, interview, March 11, 2013).

She maintained this held conception throughout the study. When asked to identify the major concepts to be taught in an upcoming unit on soil, she commented:

> Mainly it's vocabulary. I like to talk about the limiting factors and do the [interactive activity] after the [state-mandated standardized test.] [I need] three days to cover the major concepts with soil. Renewable and nonrenewable resources won't take long and I could cover that when I teach rocks and minerals. I can mention it enough for [the test] and go back. (Newman, dialogue, April 15, 2013).

Misconception #2-Assumptions about standardized testing. Throughout the study, Ms. Newman frequently referenced a concern regarding district mandated benchmark assessments and state mandated standardized testing in science. There appeared to be an emphasis from the school district on the importance of ranking teachers based on student performance on the benchmark tests. During a reflective dialogue, Ms. Newman noted:

> I have decided to stop studying earthquakes [from the 8th grade standards,] and, next week, move onto to ecology [from the 7th grade standards] because I only have two weeks before [state testing.] I thought I could use the whole two weeks to study soil, cover ecology, and review for the state test. I need at least two full days to review for

> [state testing.] Then, I can start back with the 8th grade standards after testing. (Newman, dialogue, May 15, 2013).

Her misconception was further reinforced as her students performed well on district benchmark assessments. She stated, "A comment was made at a district-level meeting that my benchmark scores were among the highest in the district."

This misconception about the importance of standardized testing appeared to impact Ms. Newman's implementation of instructional activities designed to review content that reinforced learning at the knowledge/understanding levels. She commented, "I've got to stop [my lessons] on seismic waves and go back to bacteria and protists to prepare my students for the upcoming 7th grade [district] benchmark. I also have to review genetics." Later in the semester, she designed an activity in which questions from content areas taught in the previous semester (chemical reactions, cellular processes, and genetics) were posted in various locations around the classroom. Students worked in pairs or small groups to rotate among the locations and answer the questions. The questions were mainly at the recall or understanding level such as "What is the chemical equation for photosynthesis?" or "Explain the process of diffusion."

Ms. Newman continued to express this held conception. In the exit interview conducted at the end of the study, she reflected on how she had changed in her approach to planning for instruction. She commented:

> I have little flexibility [with the district-mandated, accelerated curriculum.] I have to follow a set order for each nine-weeks [grading period] because my students have to take district-mandated benchmark tests. And, they have to be ready for [the state-mandated, standardized test] at their grade level even though we covered content from another grade level this year. (Newman, interview, June 26, 2013).

Assessing Levels of Implementation of Inquiry-based Practice

Table 4.3 displays the overall EQUIP scores by construct for Ms. Newman prior to and during the study. As noted in the table, Ms. Newman's scores ranged primarily at the pre-inquiry (level one) and developing inquiry (level two) for her entire first two years of participation within the study. Her observed practice was not indicating a transition within her practice to proficient levels of inquiry as expected. The static nature of her implementation was not noted in other participants from the school. During her participation in ongoing reflective dialogues as part of this study, Ms. Newman continued to score primarily at the developing level.

Study participant #2- Ms. Newman	Pre-study score range	Observation 1	Observation 2	Observation 3
Instruction	1-2	2	1	2
Discourse	1-2	2	2	2
Assessment	1-2	2	1	2
Curriculum	1-2	2	1	3

Table 4.3: Overall EQUIP Scores by construct for Study Participant #2-Ms. Newman

Table 4.3 displays the overall EQUIP scores by construct for Ms. Newman prior to and during the study. As noted in the table, Ms. Newman's scores ranged primarily at the pre-inquiry (level one) and developing inquiry (level two) for her entire first two years of participation within the study. Her observed practice was not indicating a transition within her practice to proficient levels of inquiry as expected. The static nature of her implementation was not noted in other participants from the school. During her participation in this study, Ms. Newman continued to score primarily at the developing level for all four constructs (see Table 4.4).

Prior to the start of the study, Ms. Newman scored between pre-inquiry and developing inquiry levels within the instruction construct. In the three observed lessons during the study, Ms. Newman continued to score within this range indicating little to no change in her level of implementation. Within the discourse construct, Ms. Newman scored at the pre-inquiry and developing level prior to the study. In the three observed lessons during the study, Ms. Newman consistently scored at the developing level indicating her implementation remained unchanged.

Ms. Newman demonstrated a developing level of implementation in her use of assessment throughout the study. Prior to the study, her EQUIP scores within this construct ranged between pre-inquiry and developing inquiry. In the three observed lessons during the study, Ms. Newman scores remained within the same range indicating a static level of implementation. Within the curriculum construct, Ms. Newman scored between pre-inquiry and developing inquiry. In the three observed lessons during the

study, Ms. Newman's scores ranged from pre-inquiry to proficient level of implementation indicating inconsistencies within her observed practice.

At the start of the study, Ms. Newman scored at the pre-inquiry and developing inquiry levels for the instruction construct. In the three observed lessons, she scored more consistently at the developing and proficient levels of inquiry. Within the discourse construct prior to the start of the study, she scored at the developing and proficient inquiry levels. In the three observed lessons during the study, Ms. Newman scored a more consistently at the proficient level of inquiry indicating a more sustained transformation of practice.

Construct	*Factors*	*Observation #1*	*Observation #2*	*Observation #3*
Instruction	Instructional strategies	2	1	2
	Order of instruction	2	1	2
	Teacher role	3	2	2
	Student role	3	2	2
	Knowledge acquisition	2	1	2
Discourse	Questioning level	2	2	3
	Complexity of questions	2	2	2
	Questioning ecology	3	1	3
	Communication pattern	2	1	2
	Classroom interactions	1	2	2
Assessment	Prior knowledge	2	2	3
	Conceptual development	2	1	2
	Student reflection	2	2	2
	Assessment type	3	1	2
	Role of assessing	2	1	2
Curriculum	Content depth	2	2	3
	Learner centrality	2	1	3
	Standards	3	1	3
	Organizing and recording information	2	1	3

Table 4.4: EQUIP Scores by factor for Study Participant #2-Ms. Newman

Table 4.4 presents the individual scores for each factor within the four constructs of EQUIP. Prior to this study, Ms. Newman consistently scored at the developing level of implementation for multiple indicators on the EQUIP during classroom observations indicating her practice at a level of developing inquiry. She was regularly observed directing the student learning. Even though she did provide opportunities for her students to explore concepts, they were given no flexibility in designing and conducting the investigation. In providing the explanations for the concepts, her students were frequently passive learners with the teacher directing all instruction.

In the evaluation of Ms. Newman's scores during the study, she continued to implement these practices as evidenced by the EQUIP scores. She scored consistently at the pre-inquiry (level one) and developing (level two) stages of implementation. Out of 57 possible scores, Ms. Newman had 12 scores at the pre-inquiry level; 33 at the developing level; and 12 at the proficient level of implementation. These scores did not clearly align with Ms. Newman's transitions within her held conceptions about inquiry-based practices expressed in the reflective dialogues. Throughout the study, she was able to articulate held conceptions; however, these understandings did not align with the observed levels of practice. She articulated held conceptions about inquiry-based practice that reflect a level of understanding as proficient. However, as she progressed within the study, she continually altered her implemented lessons by exchanging her planned instructional activities, which reflected a proficient level of understanding, with those at the developing level.

Key Findings

Two encompassing themes emerged from analysis for each participant that indicated potential barriers to an effective, sustained implementation of inquiry-based practices. These themes encapsulated held conceptions from both study participants about aspects of one' instructional practice: student motivation and student cognitive ability. Within each of these themes, several key factors were identified that served to block these teachers' acceptance and full implementation of the reform message presented within the professional development initiative.

Student motivation

Ms. Carroll revealed several held conceptions that influenced her perceptions regarding the motivation of G/T students as compared with students in grade-level classes. From the analysis of her reflection, it appeared that she wanted to blame student actions on a perceived lack of motivation without trying to question her own decision making process. First, she assumed that G/T students were completing assigned work at home, and students in her grade-level classes were unmotivated to complete assigned work at home. However, the actual underlying factors could be that G/T students were more in tune with classroom norms and had better developed skills in navigating the classroom culture. For students in the grade-level classes, many of whom are reluctant learners, the challenges within their home environments may be outweighing any motivation these students have to achieve. However, this does not necessarily mean that the G/T students are making a deliberate effort to complete assignments at home nor does it indicate that students in grade-level classes are not motivated to not complete work at

home. It could be the grade-level students are lacking the needed resources, support, and appropriate environment within their home to successfully complete their work.

Second, Ms. Carroll continually compared her perceived work ethic and motivation level of former students to her current students. For example, she stated:

> I had kids from several years ago who outshine these kids even though I was not teaching the inquiry way at that time. But, their desire and motivation to learn was so much greater. (Ms. Carroll, interview, June 24, 2013).

In these comparisons of her former students to her current ones, it was not clarified if Ms. Carroll took into consideration external factors such as changes that led to significant changes to the school's demographics over the past few years. The district had opened three new middle schools and the school's student population had been redistricted as the attendance area for the school changed.

Ms. Carroll's continued holding onto of this misconception that students who were not identified as gifted/talented were unmotivated could be masking her recognition of the need to provide an appropriate level of support for all students to be successful. As evidenced through observed lessons and responses during reflective dialogues, Ms. Carroll failed to see how her negative comments as influenced by her conceptions of her grade level students being unmotivated had an impact on student behaviors within the classroom. In addition, her negative reactions to the grade-level students who did not meet her expectations of student behavior, exacerbated situations within the classrooms thereby reinforcing student perceptions of her lack of caring. In turn, the students' behaviorss re-affirmed her conceptions about the lack student motivation. From the analysis of her reflections, it appeared that she wanted to blame student actions on a

perceived lack of motivation without trying to question her own decision making process. Her actions appeared to be contributing to an ongoing cycle of student apathy and teacher frustration.

Ms. Newman also revealed several held conceptions that shaped her perceptions regarding the motivation of G/T students. From the analysis of her reflections, it appeared that external factors had a strong influence over her decision making process. Throughout the study, Ms. Newman often remarked about feeling pressured to "cover the standards" and "move quickly through the material" in order to meet the demands of teaching the content of two grade levels within one school year. This context served to reinforce misconceptions about the role of standardized testing on designing instruction. Furthermore, Ms. Newman appeared to view G/T students as being able to learn a quantity of knowledge at a faster pace than grade-level students. Her comments indicated a held conception that the students would gain the limited mastery needed to perform on the state-mandated test with just a cursory presentation of the concepts. This reflection reinforced her understanding of how best to implement the accelerated curriculum as the students were grasping the material with her brief, teacher-centered lessons. However, she was not able to recognize how this perception did not align with a proficient level of inquiry-based practice. In fact, these G/T students probably entered her classroom with a great deal of prior knowledge and could have scored well on these tests before receiving instruction. Her held conception about the motivation of G/T students to learn vast amounts of material influenced her decisions to disregard student prior knowledge and

utilize teacher-centered methods that supported rote memorization of content rather than student conceptual understanding.

Student cognitive ability

For Ms. Carroll, her misconception regarding student cognitive ability appeared to emerge from her perceptions about the home environments of G/T students as compared to grade-level students. In the introductory interview, she stated:

> I've found that the G/T kids can noodle through the higher level thinking more easily than the regular ed kids. I don't think it's so much ability so much as it is the lack of exposure. They don't have the base knowledge that a lot of the G/T kids do. That might be limited from home environment. (Carroll, interview, February 18, 2013).

Here, she did acknowledge that the home environment does have an influence on student behaviors within the classroom, yet she did not intentionally plan to adapt her instructional practice to address this misconception. As the study progressed, Ms. Carroll became very reluctant to let go of this conception, especially as she experienced frustration when implementing changes to her instruction within her grade-level classes. In addition, her interactions with her G/T served to reinforce this held conception about the relationship between student cognitive ability and prior knowledge. As Ms. Carroll became discouraged when attempting to implement formative assessment strategies presented within the professional development initiative, she tended to place blame on the grade-level students' backgrounds rather than scaffold the use of the strategy to allow every student to be successful.

Ms. Carroll also continued to hold a conception about the ability of G/T students as compared to grade-level students to engage in productive classroom discourse. The

influence of societal norms come into play again as G/T students may have more exposure and/or a better understanding in how to engage with an adult during a conversation. They are more likely to have been taught the expectation to wait until the adult finishes his/her question before answering whereas the students in the grade-level classes may not have such a clear understanding of the role of the adult because in many cases, they are called upon to act as the adult figure in their homes/family unit.

Ms. Newman held an expectation of having her G/T students exceed the standard while learning content beyond what was being tested. She noted, "I'm the only one in the district doing the fast-paced science and I'm concerned. I don't want my kids to miss something important or not do well on the standardized test because I'm going so fast." This misconception appeared to contribute an inconsistent implementation of inquiry-based practice. This perceived pressure from external factors appeared to exacerbate her use of teacher-centered methods in an attempt to maintain control over her instructional practice.

Summary

Throughout this study, the two teachers, Ms. Carroll and Ms. Newman, participated in a series of ongoing reflective dialogues designed to uncover held conceptions regarding inquiry-based practices. The data collected from these dialogues showed that both participants described held conceptions that echoed identified best practices within inquiry-based instruction. Both teachers held a conception about giving students opportunities to explore the content before constructing an explanation, a strategy characterizing the 4E x 2 Instructional Model. Another observed conception

regarded the role of the teacher as being the facilitator of instruction rather than a giver of knowledge. Another observed conception regarded the role of formative assessment in uncovering prior knowledge in order to direct instruction. A final observed conception regarded the role of big ideas in science serving as the foundation of the curriculum opposed to discrete facts.

However, these held conceptions were not being transferred into observed practice. Recorded EQUIP scores of observed lessons for these two teachers reflected these inconsistent transformations in practice. Within some constructs, the teachers' scores remained unchanged whereas within other constructs, the scores did not indicate a sustained level of transformation. Therefore, the use of reflective dialogue within the structure of the professional development initiative did not assist these teachers in achieving full accommodation of new concepts.

The use of reflective dialogue did allow for the uncovering of held misconceptions. During the reflective dialogues, both teachers frequently referred to the influence of perceived levels of student motivation and cognitive ability on their abilities to implement inquiry-based methods. By having the teachers reflect on their decision-making processes regarding instructional practice, these concealed barriers were made visible and identified as barriers to a consistent, proficient implementation of inquiry-based methods.

CHAPTER FIVE

DISCUSSION

Summary of the Study

Traditionally, teachers have used more direct instructional methods to teach science and math although recent research (Marshall & Alston, 2014; Sinatra, Kienhues, & Hofer, 2014) has emphasized the positive student outcomes associated with the use of inquiry-based methods. Inquiry-based instruction echoes the practices and dispositions of scientists, however, this approach does not necessarily connect with expectations set forth within a culture of accountability and high-stakes testing. Rather than designing instruction to align with best practices, many science teachers have turned to implementing instructional methods that support teaching to the test such as providing large amounts of content through lecture.

However, it can be difficult for seasoned teachers to embrace new methods. Inquiry is a complex instructional strategy that has many interrelated concepts. In order to effectively implement inquiry-based methods, a teacher must be engaged in a process of conceptual change rather than rote learning. The Conceptual Change Model states that a learner (in this study, the teachers) must be engaged in cognitive dissonance about held conceptions before being able to accommodate new conceptions (Johnson, 2007; Loucks-Horsley et al., 2010; Posner et al., 1982; Vosniadou & Skopeliti, 2014). As practitioners, it can be difficult for teachers to recognize their held conceptions about their instructional practice. Their practice has become routine; therefore, they are not engaged in a

conscious evaluation of how these conceptions are influencing their decision making process (Schon, 1983).

The Cognitive Affective Model of Conceptual Change provides a more detailed framework for how teachers receive and process information about their instructional practice (Gregoire, 2003). The CAMCC states that teachers being presented a reform message must sense the message as a stress appraisal before they will engage in accepting the message. The professional development initiative in which the two study participants were involved provided multiple opportunities for teachers to receive the reform message of transforming their practice to include more consistent implementation of inquiry-based methods. The initiative advocated the philosophy of inquiry-based instruction while dissimilating strategies to help inservice teachers gain fluency in using these methods while maintaining key elements of traditional teaching pedagogy.

This study provided insight into held conceptions of teachers who were participating in professional development initiatives and who were showing inconsistent or static progress in transforming one's practice. There are many studies that outline the aspects of professional development activities that are effective in facilitating change within one's practice (Capps et al., 2012; Guskey, 2003; Johnson, 2007; Loucks-Horsley et al., 2010; Wallace & Kang, 2004). However, there are few studies that describe factors that may contribute to an understanding of teachers who do accept the reform message as presented within the professional development yet are unable to successfully implement the reform message within one's practice. Unlike many current studies, this study utilizes a framework based on conceptual change theory in order to more fully examine the

influence of one's held conceptions about inquiry-based practices as defined within the 4E x 2 Instructional Model and how those conceptions then influence the implementation of practice. By focusing on the identification of these conceptions, this study attempted to draw conclusions about the presence of any barriers to the full implementation of the inquiry-based methods.

Within the implementation of this professional development initiative, it became evident that teachers naturally classified into three groups of learners at the conclusion of the second year. One group of teachers were identified as fluent learners who embraced the 4E x 2 model and readily gained fluency and mastery of implementing inquiry-based instruction. Within the two years, they were independent learners and the need for further intervention was not evident. A second group of teachers were identified as learners who demonstrated an understanding the 4E x 2 model, however, their implementation of inquiry-based methods were inconsistent and unstable over time. These teachers had a good grasp of the concepts of inquiry-based instruction; however, their understanding did not consistently translate into their practice. A third group of teachers were identified as those who were making no significant gains through the PDI. Their conceptions of inquiry-based instruction and the implementation of the methods were limited. Further work was needed to help these teachers harness the benefits of the professional development initiative for themselves and their students. This study was conceptualized to develop a deeper understanding of the conceptions of inquiry-based instruction held by teachers in groups two and three. In addition, this study was proposed to systematically

examine and identify specific characteristics of these teachers as well as any barriers present to a sustained implementation of the 4E x 2 model.

This study engaged two middle school science teachers, one from the second identified group and one from the third identified group, in a systematic evaluation and reflection of their instructional practice as it related to the implementation of the inquiry-based methods within their classrooms. Prior the study, both teachers were able to articulate held conceptions about inquiry-based methods; however, they demonstrated inconsistent use of inquiry-based practices within their classrooms. During the study, both teachers continued to articulate correct conceptions about inquiry-based instruction through the interviews and reflective dialogues. Their conceptions aligned with the factors within the EQUIP and 4E x 2 model indicating that they had received the reform message presented within the ongoing professional development initiative. However, their observed practice did not reflect a proficient understanding or implementation of inquiry-based methods. The reflective dialogues served as a tool to uncover held misconceptions, which were then identified as potential barriers to the sustained implementation of inquiry-based practice. Finally, the reflective dialogues served to engage teachers in the cognitive dissonance/stress appraisal needed for the identification and accommodation of new concepts.

Research Question #1-Articulated conceptions of inquiry-based practice

At the start of the study, Ms. Carroll had inconsistent scores on EQUIP yet she could consistently articulate an understanding of inquiry-based practices at the proficient level. She also firmly believed she was implementing those articulated practices at the

proficient level. This assimliation of the conceptional knowledge, as described within both the CCM and CAMCC, occurs when the practitioner has yet to fully replace held conceptions with the new information. Full conceptual understanding does not occur until the conceptions have been accommodated (Gregoire, 2003; Posner et al., 1982), and the lack of accommodation can serve as a barrier to the consistant implementation of the practice.

In the analysis of the introductory interview and subsequent reflective dialogues, the researcher was able to uncover some of Ms. Carroll's held conceptions and misconceptions. The identified misconceptions provided some explanation as to why Ms. Carroll was unable to successfully implement inquiry-based methods. These misconceptions were observed to function as a barrier to her full accommodation of the reform message (Gregoire, 2003.) These misconceptions were supported by Ms. Carroll's affective and emotional perceptions regarding her perceived differences between students in her classes who were identified as gifted and talented versus students who were in grade-level science classes.

Through the use of reflective dialogue, these emotional perceptions and resulting misconceptions were able to be identified as barriers to the successful implementation of inquiry-based methods. In addition, these misconceptions were able to be addressed through subsequent dialogues. As Ms. Carroll was asked to reflect upon the factors she perceived as influencing her decision making process, the researcher was able to determine links between the held misconceptions and observed instructional practice. After establishing the link, the researcher was able to assist Ms. Carroll in modifying her

approach in regards to the use of classroom discourse, especially within the grade-level classes. For example, Ms. Carroll continued to hold the misconception that G/T students brought more prior knowledge into the classroom and were, therefore, more motivated to learn. She begin to indicate a shift away from her misconception regarding the cognitive ability of her grade-level students in that she began to implement strategies to scaffold the learning process. In turn, these students begin to demonstrate stronger understandings of the content.

Unlike Ms. Carroll, Ms. Newman consistently scored on the EQUIP at the developing inquiry level. She was observed unable to implement instructional practice at the proficient level after two years of participating in the professional development initiative. However, like Ms. Carroll, Ms. Newman could articulate an understanding of proficient inquiry-based practices. Ms. Newman also perceived many of her implemented inquiry-based practices to be at the proficient level, especially within the instruction construct. However, Ms. Newman did recognize that she was unable to implement some of the practices, especially within the construct of discourse.

Through the use of reflective dialogue, two key misconceptions regarding Ms. Newman's perceptions of her instructional practice were identified. These ideas, in turn, were observed to serve as a barrier to her full accommodation of the reform message (Gregoire, 2003). Unlike Ms. Carroll, Ms. Newman was able to consistently plan a proficient inquiry-based lesson containing all of the elements of the 4E x 2 model. She also consistently referred to these elements of her lesson plan during reflective diagloues. However, when observed in the classroom Ms. Newman would often modify the

activities within the lesson plan and revert to a teacher-centered instructional approach. As expressed within her reflective dialogues, Ms. Newman described how the presentation of the 4E x 2 model was a new concept to her although she had been teaching science for over 20 years. Therefore, as Ms. Newman encountered feelings of being pushed beyond her comfort zone (Downey et al., 2004), she adjusted her actions to bring her approach to instruction more in align with what was normative. At these times within her lessons, she perceived a threat to her practice and thus, sought a pathway to elminiate the uncertainty.

Throughout the course of the study, Ms. Newman continued to demonstrate the impact of her firmly held conceptions regarding the need to provide only coverage of the content within the confines of an accelerated curriculum. And, this conception appeared to grow stronger towards the end of the school year as she felt pushed even more away from her comfort zone as she perceived the inability to "cover all the required material" before the exam period. Ms. Newman also continued to hold her misconception regarding the emphasis of standardized testing on her instructional decision making thereby reinforcing her use of instructional strategies aimed primarily at the recall level. Therefore, she moved further away from the use of effective inquiry-based practices and reverted to teacher-centered instructional strategies in an attempt to relieve the stress being generated from this disconnect between her assimilated concepts and the situational factors within her classroom environment. In this case, the stress appraisal message became too overwhelming to be accepted (Gregoire, 2003).

Research Question #2-Representations of held conceptions in instructional practice

In many instances, these teachers held conceptions that aligned with the framework of inquiry-based instruction posed within the 4E x 2 Instructional Model as evidenced by responses given during reflective dialogues and the interviews. However, the instructional-decision making processes of these teachers as evidenced in observed lessons were more affected by identified misconceptions about factors influencing student motivation and perceptions of cognitive ability than held conceptions about inquiry-based instruction. These misconceptions appeared to be serving as barriers to a consistent implementation of inquiry-based methods at a proficient level as they were also influencing motivational and affective factors for the participants (Gregoire, 2003). Through the use of reflective dialogue, these misconceptions were identified and then addressed in subsequentconversations in order to promote the needed dissonance to recognize the held conception and then fully accommodate the new information (Posner et al., 1982)

For Ms. Carroll, there appeared to be a greater alignment between conceptions and observed practice within the instruction and curriculum constructs. During observed lessons, she consistently demonstrated a proficient level of implementation of these inquiry-based practices. In turn, her held conceptions about the constructs of discourse and assessment were often misaligned with her practice. During observed lessons, she often utilized practices more aligned with a developing level of implementation rather than at the proficient level. During the course of the study, Ms. Carroll began to demonstrate a change in her held conceptions about the need for using differentiated instruction and assessment for her G/T and grade-level classes to support student

achievement. As these misconceptions were identified and addressed during subsequent dialogues, Ms. Carroll began to implement noted changes within her use of discourse to accommodate for diverse student learning needs.

For Ms. Newman, there appeared to be a greater alignment between conceptions and observed practice within the discourse and assessment constructs. In her reflections, Ms. Newman noted that she had purposefully selected these two areas for her individual professional development plan. In turn, her held conceptions about instruction and curriculum were often misaligned with her practice. At the start of the study, her level of implementation within these two constructs was consistently observed at the developing level. However, as she reflected on her use of inquiry-based methods, she began to transform her practice to align more with proficient levels of implementation.

Throughout the course of the study, Ms. Newman began to alter her held conceptions and make modifications to her use of instruction and curriculum within her practice. However, she would revert to more teacher-directed practice as she felt she was not moving fast enough through the content to meet the expectations of the district-mandated curriculum. In addition, Ms. Newman did not demonstrate any noticeable changes to her implementation of discourse or assessment practices. As noted within her reflections, she perceived having a strong command of the use of effective assessment strategies. Therefore, she was not able to enter into a state of dissonance regarding her practice even though she was asked repeatedly during the dialogues to analyze her decision-making process regarding her use of assessment within a lesson. The dialogue sessions were not effective in bringing about the recognition of a stress appraisal

regarding her held conception; therefore, she could not enter into the process of conceptual change (Gregoire, 2003).

Research Question #3-Evidence of conceptual change

As conceptual change theory explains, for a learner to want and be able to accommodate new conceptions in place of previously held ones, the learner must encounter dissonance with that held conception (Downey et al., 2004; Johnson, 2007; Posner et al., 1982). It can be difficult for practitioners to experience dissonance as they are comfortable with their skills and can perform using minimal cognitive capacity. As evidenced by the findings from this study, the use of reflective dialogue was an effective tool for the facilitator to uncover held conceptions regarding instructional practice. However, the use of reflective dialogue did not create the needed dissonance for the study participants to consistently translate these identified held conceptions into practice (Gregoire, 2003).

The use of reflective dialogue can also assist teachers in clarifying their understanding and providing a scaffold specific to each teacher as she attempted to implement new instructional strategies within the framework of the professional development initiative (Ebert & Crippen, 2010). However, the use of reflective dialogue as an added intervention to the professional development initiative was not effective in sustaining a transformation in practice. By its nature, reflective dialogue is designed for participants to contemplate on their held conceptions. As discovered in this study, that is not enough by itself to engage practitioners in the needed cognitive dissonance to lead to conceptual change.

Teaching is a very complex process, which can be impacted not only by the environmental factors within the classroom but also by external factors. These external factors can stem from school, district, and state level policies as well as local community constructs. Within this study, external factors had a great influence on the participants' abilities to fully implement inquiry-based instruction. In addition, these teachers' participation within the professional development initiative pushed them out of their zone of proximal development without providing appropriate supports. Therefore, they both responded by unconsciously resisting the full accommodation of the concepts (Gregoire, 2003).

Implications

As noted in the findings of this study, the participants had a difficult time in identifying held conceptions about their instructional practice. The examination of when and how teachers make shifts in practice or dispositions based on personal reflections can inform professional development models and theoretical models for the learning professional. As conceptual change theory explains, one's constructed understandings of the phenomena encountered in the surrounding environment are more easily accommodated as one repeatedly engages with the concepts (Posner et al., 1982). Hence, practitioners who have collected a great deal of experience and interaction with held conceptions, can have difficulty in identifying those conceptions as those understandings have melded into their established practice. This was evidenced in within the multi-year professional development initiative as the two participants in this study were observed inconsistently implementing the elements of effective inquiry-based instruction. It was

determined that the professional development met the hallmarks of an effective initiative yet these two teachers continued to hold misconceptions about the components of inquiry-based practice as defined by the EQUIP and the 4E x 2 Instructional Model.

Overall, the use of reflective dialogue within this professional development initiative provided a way to uncover barriers and serve as a means to address potential bottlenecks to the implementation of inquiry-based practice. Within current research, there has been no clear way identified to support all teachers; a one-size fits all approach to professional development does not address the needs of all learners (Capps et al., 2012; Gusky & Yoon, 2009). The findings from this study suggest a need to generate ways to break down the complex charge placed on science teachers to implement inquiry-based instruction. Assisting practitioners in analyzing their practice in order to identify areas of deficiency is a multi-step process that includes accounting for personal dispositions, external factors, teacher background and training. Reflective dialogue can provide teacher-specific scaffolding as practitioners attempt to modify their practice (Downey et al., 2004). By establishing a safe, supportive rapport with the teachers, they can be more willing to work through the identified barriers and make substantial process in transforming their practice.

Therefore, an additional intervention was needed for these teachers. Research about the use of reflective practice to assist practitioners with engaging in an analysis of their practice indicated this process as a possible tool for these teachers to begin maintaining transformations in their practice. Through the use of reflective dialogues, it was intended that participants would be able to better articulate their held conceptions

thereby leading to the identification and acceptance of any held misconceptions. However, the identification of held misconceptions is especially crucial as teachers prepare to implement inquiry-based practices as this overall concept can be ambiguous and difficult to define.

The current structure of the professional development initiative did not accommodate for the identification of misconceptions or the influence of external barriers on the accommodation of the concepts about inquiry-based instruction. A sub-intervention is needed that runs parallel to uncover external factors impacting a teacher's ability to fully accommodate new concepts. For the teachers within this study, they were reacting to external factors but were not always able to articulate the influence of these factors on their instructional decision making process. Therefore, the use of a reflective practice model provides an opportunity for practitioners to uncover the relationship between the factors and one's instructional decision making process.

Within this study, the participants could have benefited from additional interventions such as viewing recording of their inquiry-based lessons in order to provide a more concrete representation of the disconnect between held conceptions and implementation. In addition, participants could have received instruction on the four constructs on the EQUIP in order to more fully develop their understanding of the facets identified by instrument as leading to a proficient level of implementation. Also, participants could have been given sample recorded lesson to score on the constructs so that they could have more tangible examples of the various levels of implementation.

Then, they could be assisted in comparing and contrasting what was observed in the sample lessons with their own practice.

Conclusion

As indicated within the findings of this study, teachers as practitioners are constantly having to construct understandings about the observations they make within their environment, the classroom. As these understandings or conceptions are being constructed, they are tacitly impacting the teacher's decision making process. The decisions produce either a positive or negative result thereby influencing how tightly the practitioner holds onto those conceptions. Teachers who are perceived as being resistant to the implementation of the reform message may need a way in which to express held conceptions as well as their attached emotional and affective factors regarding their instructional practice.

Designing effective professional development experiences for teachers is a complex process. For a practitioner to be able to successfully transform one's practice, the professional development must be multi-dimensional and person-specific in order to lead to sustained transformations of practice (Capps, et al, 2012; Guskey, 2003). The use of a reflective practice model such as one-on-one reflective dialogues can begin to provide this needed, individualistic support. The process of implementing a reflective practice model is time, labor, and effort intensive on the part of the professional development providers. However, by including an element of reflectivity within a professional development initiative, specific barriers to the full implementation can be identified and accommodated. Short of doing this, overall success in the implementation

of the intervention cannot be achieved or sustained. Some barriers are easier to identify and remove; however, those barriers being influenced by strongly held conceptions are harder to identify from only observing teacher practice. The use of a reflective practice model can enable professional development providers to more clearly understand and articulate potential roadblocks to a successful implementation.

For many practitioners, who have been forced to accept one new intervention after another without receiving the appropriate support and scaffolding, professional development initiative are seen as "this too shall pass" as the interventions are frequently abandoned after a brief period of trial. Many of these interventions abandoned due to the lack of identification of those barriers, whether visible or invisible. By utilizing a reflective practice model, professional development providers and practitioners can better understand the needed support for a sustained transformation in practice, In turn, the overall impact on instruction can lead to a deeper level of understanding for students (Downey et al., 2004).

Providers of professional development can strengthen the significance of their reform message by including a reflective dialogue component within the initiative. By engaging participants in reflective dialogues, one can more accurately assess held conceptions and misconceptions. In addition, one can ascertain how those held beliefs may be acting as barriers to the successful implementation of the reform message. This is especially important when the reform message is constructivist-oriented as this type of model is asking teachers to accommodate new conceptions regarding their instructional practice. Held conceptions and misconceptions can often block full accommodation of

the new conceptions, especially if teachers are allowed to simply assimilate the new ideas within their prior knowledge.

Therefore, as teachers are introduced to new conceptions about their practice, they must engage with their held conceptions and link these new ideas to prior knowledge. For some teachers, this is a difficult process without having an intervention such as engaging in reflective dialogues in order to identify held conceptions and evaluate the influence of those conceptions on current practice. And, if teachers simply receive the new information without being able to fully process the implications of these concepts, they will continue to implement the same methods even though they perceive they have adopted the new methods. This cycle of simply assimilating the new knowledge within one's currently held conceptions does not lead to sustained transformations in practice.

APPENDICES

Appendix A

The Electronic Quality of Inquiry Protocol (EQUIP)

IV. Instructional Factors					
Construct Measured		*Pre-Inquiry (Level 1)*	*Developing Inquiry (2)*	*Proficient Inquiry (3)*	*Exemplary Inquiry (4)*
I1.	Instructional Strategies	Teacher predominantly lectured to cover content.	Teacher **frequently lectured** and/or used demonstrations to explain content. Activities were **verification only**.	Teacher **occasionally lectured**, but **students were engaged in activities** that helped develop conceptual understanding.	Teacher occasionally lectured, but students were engaged in investigations that **promoted strong conceptual understanding**.
I2.	Order of Instruction	Teacher explained concepts. Students either did not explore concepts or did so only after explanation.	Teacher asked **students to explore concept before receiving explanation**. Teacher explained.	Teacher asked students to **explore before explanation**. **Teacher and students explained**.	Teacher asked students to explore concept before explanation occurred. Though perhaps prompted by the teacher, **students provided the explanation**.
I3.	Teacher Role	Teacher was center of lesson; rarely acted as facilitator.	**Teacher was center** of lesson; **occasionally** acted as **facilitator**.	Teacher **frequently** acted as facilitator.	Teacher **consistently and effectively** acted as a facilitator.
I4.	Student Role	Students were consistently passive as learners (taking notes, practicing on their own).	**Students were active to a small extent** as learners (highly engaged for very brief moments or to a small extent throughout lesson).	**Students were active as learners** (involved in discussions, investigations, or activities, but not consistently and clearly focused).	Students were **consistently and effectively active as learners** (highly engaged at multiple points during lesson and clearly focused on the task).
I5.	Knowledge Acquisition	Student learning focused solely on mastery of facts, information, and/or rote processes.	Student learning focused on **mastery of facts** and process skills without much focus on understanding of content.	Student learning required **application of concepts** and process skills in new situations.	Student learning required **depth of understanding** to be demonstrated relating to content and process skills.

V. *Discourse Factors*					
Construct Measured		*Pre-Inquiry (Level 1)*	*Developing Inquiry (2)*	*Proficient Inquiry (3)*	*Exemplary Inquiry (4)*
D1.	Questioning Level	Questioning rarely challenged students above the remembering level.	Questioning rarely challenged students above the **understanding level**.	Questioning challenged students **up to application or analysis levels**.	Questioning challenged students at various levels, **including at the analysis level or higher; level was varied to scaffold learning.**
D2.	Complexity of Questions	Questions focused on one correct answer; typically short answer responses.	Questions focused **mostly on one correct answer;** some open response opportunities.	Questions **challenged students to explain, reason, and/or justify**.	Questions required students to explain, reason, and/or justify. **Students were expected to critique others' responses.**
D3.	Questioning Ecology	Teacher lectured or engaged students in oral questioning that did not lead to discussion.	Teacher occasionally **attempted to engage students in discussions** or investigations but was not successful.	Teacher **successfully engaged students** in open-ended questions, discussions, and/or investigations.	Teacher **consistently and effectively engaged students** in open-ended questions, discussions, investigations, and/or reflections.
D4.	Communication Pattern	Communication was controlled and directed by teacher and followed a didactic pattern.	Communication was **typically controlled and directed by teacher** with occasional input from other students; mostly didactic pattern.	**Communication was often conversational** with some student questions guiding the discussion.	Communication was **consistently conversational with student questions often guiding the discussion**.
D5.	Classroom Interactions	Teacher accepted answers, correcting when necessary, but rarely followed-up with further probing.	Teacher or another student **occasionally followed-up student response** with further low-level probe.	Teacher or another student **often followed-up response** with engaging probe that required student to **justify reasoning or evidence**.	Teacher **consistently and effectively facilitated rich classroom dialogue** where evidence, assumptions, and reasoning were challenged by teacher or other students.

VI. *Assessment Factors*					
Construct Measured		*Pre-Inquiry (Level 1)*	*Developing Inquiry (2)*	*Proficient Inquiry (3)*	*Exemplary Inquiry (4)*
A1.	Prior Knowledge	Teacher did not assess student prior knowledge.	Teacher **assessed student prior knowledge but did not modify instruction** based on this knowledge.	Teacher assessed student prior knowledge and then **partially modified instruction** based on this knowledge.	Teacher assessed student prior knowledge and then **modified instruction** based on this knowledge.
A2.	Conceptual Development	Teacher encouraged learning by memorization and repetition.	Teacher encouraged **product- or answer-focused** learning activities that **lacked critical thinking.**	Teacher encouraged **process-focused** learning activities that **required critical thinking**.	Teacher encouraged process-focused learning activities that involved **critical thinking that connected learning with other concepts**.
A3.	Student Reflection	Teacher did not explicitly encourage students to reflect on their own learning.	Teacher explicitly encouraged students to **reflect** on their learning but only at a minimal **knowledge level**.	Teacher explicitly encouraged students to **reflect** on their learning at an **understanding level**.	Teacher consistently encouraged students to reflect on their learning at multiple times throughout the lesson; **encouraged students to think at higher levels**.
A4.	Assessment Type	Formal and informal assessments measured only factual, discrete knowledge.	Formal and informal assessments **measured mostly factual, discrete knowledge**.	Formal and informal assessments **used both factual, discrete knowledge and authentic measures**.	Formal and informal assessment methods **consistently and effectively used authentic measures**.
A5.	Role of Assessing	Teacher solicited predetermined answers from students requiring little explanation or justification.	Teacher **solicited information from students to assess understanding**.	Teacher solicited explanations from students to assess **understanding and then adjusted instruction accordingly**.	Teacher frequently and effectively assessed student understanding and adjusted instruction accordingly; **challenged evidence and claims made; encouraged curiosity and openness**.

VII. Curriculum Factors					
Construct Measured		*Pre-Inquiry (Level 1)*	*Developing Inquiry (2)*	*Proficient Inquiry (3)*	*Exemplary Inquiry (4)*
C1.	Content Depth	Lesson provided only superficial coverage of content.	Lesson provided **some depth** of content but with **no connections made to the big picture.**	Lesson provided depth of content with **some significant connection** to the big picture.	Lesson provided depth of content with **significant, clear, and explicit connections** made to the big picture.
C2.	Learner Centrality	Lesson did not engage learner in activities or investigations.	Lesson provided **prescribed activities** with anticipated results.	Lesson allowed for **some flexibility during investigation** for student-designed exploration.	Lesson provided **flexibility for students to design and carry out** their own investigations.
C3.	Integration of Content and Investigation	Lesson either content-focused or activity-focused but not both.	Lesson provided poor integration of content with activity or investigation.	Lesson **incorporated student investigation that linked well with content**.	Lesson **seamlessly integrated the content and the student investigation**.
C4.	Organizing & Recording Information	Students organized and recorded information in prescriptive ways.	**Students had only minor input as to how to organize and record information**.	Students regularly organized and recorded information in **non-prescriptive ways**.	Students organized and recorded information in **non-prescriptive** ways that allowed them to **effectively communicate their learning.**

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Appendix B

Questions for Semi-structured Interviews

1. How do you define/describe inquiry-based instruction in your classroom?
2. What advantages do you see in using inquiry-based instruction for your students?
3. What disadvantages do you see in using inquiry-based instruction for your students?
4. How do you decide what to teach and what not to teach? How do you decide when to move on to new concepts?
5. Describe how you designed an inquiry-based lesson for your classroom.
6. Describe how you use discourse within your classroom.
7. Describe how you use assessment within your classroom.
8. How do you view your role as a teacher? How do you view the role of the student in your classroom?

Appendix C

Sample Questions Used Within Reflective Dialogues

1. In planning your lessons and thinking about implementing inquiry-based instruction, what factors influenced your decisions about your instructional practice to help students construct understanding in today's lesson?
2. How did these factors impact your assessment of how your students were able to demonstrate their understanding of the concepts?
3. What specific area from the EQUIP [instruction, discourse, assessment, curriculum] would you identify as a strength?
4. What specific area from the EQUIP [instruction, discourse, assessment, curriculum] would you identify as an area of improvement?
5. In focusing on this area, what specific instructional strategies could be used in the next unit of instruction to address this area?

REFERENCES

Abd-El-Khalick, F., BouJaoude, S., Duschl, R., Lederman, N. G., Mamlok-Naaman, R., Hofstein, A., & Tuan, H. (2004). Inquiry in science education: International perspectives. *Science Education, 88*(3), 397-419.

American Association for the Advancement of Science. (1993). *Project 2061: Benchmarks for science literacy*. Oxford University Press.

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education, 59*(5), 389-407.

Biemans, H. J. A., Deel, O. R., & Simons, P. R. (2001). Differences between successful and less successful students while working with the CONTACT-2 strategy. *Learning & Instruction, 11*(4), 265-282.

Bodner, G., Klobuchar, M., & Geelan, D. (2001). The many forms of constructivism. *Journal of Chemical Education, 78*, 1107-1133.

Boyatzis, R. E. (1998). *Transforming qualitative information: Thematic analysis and code development*. Thousand Oaks, CA: SAGE Publications.

Bransford, J. D., Brown, A.L., & Cocking, R. R. (1999). *How people learn: Brain, mind, experience, and school*. Washington, DC: National Academy Press.

Bybee. R. W. (2002). Scientific inquiry, student learning, and the science curriculum. In Bybee, R. W. (Ed). (2002). *Learning science and the science of learning* (pp. 25-35). Arlington, VA: NSTA Press.

Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A., & Landes, N. (2006). The BSCS 5E instructional model: Origins and effectiveness. *Colorado Springs, CO: BSCS, 5*, 88-98.

Camburn, E. M. (2010). Embedded teacher learning opportunities as a Site for Reflective Practice: An exploratory study. *American Journal of Education*, 116, 463-489.

Carey, S. (2000). Science education as conceptual change. *Journal of Applied Developmental Psychology, 21*(1), 13-19.

Capps, D., Crawford, B., & Constas, M. (2012). A review of empirical literature on inquiry professional development: Alignment with best practices and a critique of the findings. *Journal of Science Teacher Education, 23*(3), 291-318. doi:10.1007/s10972-012-9275-2

Chan, C., Burtis, J., & Bereiter, C. (1997). Knowledge building as a mediator of conflict in conceptual change. *Cognition & Instruction, 15*(1), 1-40.

Chinn, C. A., & Brewer, W. F. (1993). The role of anomalous data in knowledge acquisition: A theoretical framework and implications for science education. *Review of Educational Research, 63*(1), 1-49.

Cohen, D. K. (1990). A revolution in one classroom: The case of Mrs. Oublier. *Educational Evaluation and Policy Analysis, 12*(3), 311-329.

Collins, A. (2002). How students learn and how teachers teach. In Bybee, R. W. (Ed). (2002). *Learning science and the science of learning* (pp. 3-11). Arlington, VA: NSTA Press.

Creswell, J. W. (2009). Research Design: Qualitative, quantitative, and mixed methods approaches (3rd ed.). Thousand Oaks, CA: SAGE Publications.

Dong, L, Marshall, J, & Wang, J. (2009) *A web-based collaboration environment for K-12 math and science teachers.* Paper presented at the ASEE/IEEE Frontiers in Education Conference, San Antonio, TX.

Downey, C. J., Steffy, B. E., English, F. W., Frase, L. E., and Poston, Jr, W. K. (2004). *The three-minute classroom walk-through: Changing school supervisory practice one teacher at a time*. Thousand Oaks, CA: Corwin Press.

Ebert, E. K., & Crippen, K. J. (2010). Applying a cognitive-affective model of conceptual change to professional development. *Journal of Science Teacher Education, 21*(3), 371-388. doi:10.1007/s10972-009-9183-2

Every Student Succeeds Act, 114-95 § 1177 (2015-2016).

Eylon, B., & Linn, M. (1988). Learning and instruction: An examination of four research perspectives in science education. *Review of Educational Research, 58*(3), 251-301.

Fletcher, S. S., & Luft, J. A. (2011). Early career secondary science teachers: A longitudinal study of beliefs in relation to field experiences. *Science Education, 95*(6), 1124-1146. doi:10.1002/sce.20450

Franke, M. L., Carpenter, T. P., Levi, L., & Fennema, E. (2001). Capturing Teachers' Generative Change: A follow-up study of professional development in mathematics. *American Educational Research Journal, 38*(3), 653-689.

Gallagher, S. A., & Stepien, W. J. (1995). Implementing problem-based learning in science classrooms. *School Science & Mathematics, 95*(3), 136.

Gregoire, M. (2003). Is it a challenge or a threat? A dual-process model of teachers' cognition and appraisal processes during conceptual change. *Educational Psychology Review, 15*(2), 147.

Guskey, T. R. (2003). What makes professional development effective? *Phi Delta Kappan, 84*(10), 748.

Guskey, T. R., & Yoon, K. S. (2009). What works in professional development? *Phi Delta Kappan, 90*(7), 495-500.

Ireland, J., Watters, J., Brownlee, J., & Lupton, M. (2012). Elementary teacher's conceptions of inquiry teaching: Messages for teacher development. *Journal of Science Teacher Education, 23*(2), 159-175. doi:10.1007/s10972-011-9251-2

Jeanpierre, B., Oberhauser, K., & Freeman, C. (2005). Characteristics of professional development that effect change in secondary science teachers' classroom practices. *Journal of Research in Science Teaching, 42*(6), 668-690. doi:10.1002/tea.20069

Johnson, C. C. (2007). Whole-school collaborative sustained professional development and science teacher change: Signs of progress. *Journal of Science Teacher Education, 18*(4), 629.

Jorgenson, O., Cleveland, J., & Vanosdall, R. (2004). *Doing good science in middle school: A practical guide to inquiry-based instruction*. Arlington, VA: National Science Teachers Association Press.

Kayapinar, U. (2016). A study on reflection in in-service teacher development: Introducing reflective practitioner development model. *Educational Sciences: Theory & Practice, 16*(5), 1671-1691. doi:10.12738/estp.2016.5.0077

Knight, B. (1996). Reflecting on "reflective practice." *Studies in the Education of Adults, 28*(2), 162.

Levin, B. (2008). Attracting and retaining good teachers. *Phi Delta Kappan, 90*(3), 223-224.

Lewis, T. (2007). Social inequality in education: A constraint on an American high-skills future. *Curriculum Inquiry, 37*(4), 329-349. doi:10.1111/j.1467-873X.2007.00390.x

Limon, M. (2001). On cognitive conflict as an instructional strategy for conceptual change: a critical appraisal. *Learning and Instruction, 11*, 357-380.w

Lincoln, Y. S. & Guba, E. G. (1985). *Naturalistic inquiry*. Thousand Oaks, CA: SAGE Publications.

Linn, M., Eylon, B., Rafferty, A., & Vitale, J. (2015). Designing instruction to improve lifelong inquiry learning. *Eurasia Journal of Mathematics, Science, & Technology, 11*(2), 217-225.

Loucks-Horsley, S., Stiles, K. S., Mundry, S., Love, N., & Hewson, P. W. (2010). *Designing professional development for teachers of science and mathematics* (3rd ed.). Thousand Oaks, CA: Corwin Press.

Marshall, J. (2007). 4E x 2 Instructional Model [Electronic Version]. Retrieved from www.clemson.edu/iim

Marshall, J. (2013). *Succeeding with inquiry in science and math classroom*. Alexandria, VA: ASCD.

Marshall, J., Horton, B., & Smart, J. (2009). 4E × 2 Instructional Model: Uniting three learning constructs to improve praxis in science and mathematics classrooms. *Journal of Science Teacher Education, 20*(6), 501-516. doi:10.1007/s10972-008-9114-7

Marshall, J., Horton, R., & White, C. (2009). EQUIPping teachers: A protocol to guide and improve inquiry-based instruction. *The Science Teacher, 76*(4), 46-53.

Marshall, J., Smart, J., & Horton, R. (2010). The design and validation of EQUIP: An instrument to assess inquiry-based instruction. *International Journal of Science & Mathematics Education, 8*(2), 299-321. doi:10.1007/s10763-009-9174-y

Marshall, J.C. & Alston, D.M. (2014). Effective, sustained inquiry-based instruction promotes higher science proficiency among all groups: A 5-year analysis. *Journal of Science Teacher Education*, *25*,807. doi:10.1007/s10972-014-9401-4

Marshall, J. C. & Horton, R. M. (2010) *Developing, assessing, and sustaining inquiry-based instruction: A guide for math and science teachers and leaders.* Germany: VDM Verlag.

Marshall, J. C., Horton, B., Smart, J., & Llewellyn, D. (2008). *EQUIP: Electronic Quality of Inquiry Protocol*: Retrieved from Clemson University's Inquiry in Motion Institute, www.clemson.edu/iim

Marshall, J. C., Smart, J., Lotter, C., & Sirbu, C. (2011). Comparative analysis of two inquiry observational protocols: Striving to better understand the quality of teacher-facilitated inquiry-based instruction. *School Science & Mathematics, 111*(6), 306-315. doi:10.1111/j.1949-8594.2011.00091.x

Members of the "Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5" Committee. (2010). *Rising above the gathering storm, revisited: Rapidly approaching category 5*. Washington, DC: National Academies Press.

Merriam, S. B. (2009). *Qualitative research: A guide to design and implementation* (3rd ed). San Francisco, CA: Jossey-Bass.

Michaels, S., Shouse, A. W., & Schweingruber, H. A. (2008). *Ready, set, science!* Washington, DC: National Academies Press.

National Center for Education Statistics. (2012). *The nation's report card: Science 2011 national assessment of educational progress at grade 8* (NCES 2012-465). Washington, DC: Institute of Education Sciences, U. S. Department of Education.

National Commission on Excellence in Education. (1983). *A Nation at Risk: The Imperative for Educational Reform*. Washington, DC: U.S. Department of Education.

National Research Council. (1996). National science education standards. Washington, DC: National Academies Press.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

National Science Teachers Association. (2004). *Position statement on scientific inquiry*. http://www.nsta.org/pdfs/PositionStatement_ScientificInquiry.pdf

NGSS Lead States. (2013). *Next Generation Science Standards: For states, by states.* Washington, DC: National Academies Press. www.nextgenscience.org/next-generation-science-standards.

NEA Survey: Nearly Half Of Teachers Consider Leaving Profession Due to Standardized Testing - NEA Today. http://neatoday.org/2014/11/02/nea-survey-nearly-half-of-teachers-consider-leaving-profession-due-to-standardized-testing-2/

Nelson, T. H., Deuel, A., Slavit, D., & Kennedy, A. (2010). Leading deep conversations in collaborative inquiry groups. *Clearing House, 83*(5), 175-179. doi:10.1080/00098650903505498

Nespor, J. (1987). The role of beliefs in the practice of teaching. *Journal of Curriculum Studies, 19*(4), 317-28.

NO CHILD LEFT BEHIND ACT, 20 U.S.C. § 6319 (2001).

Odom, A., & Kelly, P. (2001). Integrating concept mapping and the learning cycle to teach diffusion and osmosis concepts to high school biology students. *Science Education*, *85*(6), 615-35.

OECD. (2013). *PISA 2012 Assessment and Analytical Framework: Mathematics, Reading, Science, Problem Solving and Financial Literacy*. OECD Publishing. http://dx.doi.org/10.1787/9789264190511-en

O'Neill, D. K., & Polman, J. L. (2004). Why educate little scientists? Examining the potential of practice-based scientific literacy. *Journal of Research in Science Teaching*, *41*(3), 234-266.

Ozdemir, N. & Clark, D. B. (2007). An overview of conceptual change theories. *Eurasia Journal of Mathematics, Science & Technology Education*, *3*(4), 351-361.

Peter D. Hart Research Associates (2005). Rising to the challenge: Are high school graduates prepared for college and work? Washington, DC: Author/Public Opinion Strategies. http://www.achieve.org/files/pollreport_0.pdf

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66*(2), 211-227.

Raines, P. & Shadiow, L. (1995). Reflection and teaching: The challenge of thinking beyond the doing. *Clearing House, 68*(5), 271.

Rebore, R. W. (2012). *The essentials of human resources administration in education*. Upper Saddle River, NJ: Pearson Education, Inc.

Savasci, F., & Berlin, D. (2012). Science teacher beliefs and classroom practice related to constructivism in different school settings. *Journal of Science Teacher Education, 23*(1), 65-86. doi:10.1007/s10972-011-9262-z

Schmitt, V. L. (2004). The relationship between middle level grade span configuration, professional development, and student achievement. *Research in Middle Level Education Online, 27*(2), 1-17.

Schon, D. A. (1983). *The reflective practitioner*. New York: Basic Books, Inc.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Sinatra, G. M., Kienhues, D., & Hofer, B. K. (2014). Addressing challenges to public understanding of science: Epistemic cognition, motivated reasoning, and conceptual change. *Educational Psychologist, 49*(2), 123-138.

Stake, R. E. (2006). *Multiple case study analysis*. New York: The Guilford Press.

Tobin, K., & McRobbie, C. J. (1996). Cultural myths as constraints to the enacted science. *Science Education, 80*(2), 223.

von Glasersfeld, E. (1989). Cognition, construction of knowledge, and teaching. *Synthese, 80*(1), 121-140.

Vosniadou, S. (1996). Towards a revised cognitive psychology for new advances in learning and instruction. *Learning & Instruction, 6*(2), 95-109.

Vosniadou, S., Ioannides, C., Dimitrakopoulou, A., & Papademetriou, E. (2001). Designing learning environments to promote conceptual change in science. *Learning & Instruction, 11*(4), 381-419.

Vosniadou, S. & Skopeliti, I. (2014). Conceptual change from the framework theory side of the fence. *Science & Education, 2*3 (7), 1427-1455. doi:10.1007/s11191-013-9640-3

Vosniadou, S., & Verschaffel, L. (2004). Extending the conceptual change approach to mathematics learning and teaching. *Learning and Instruction, 14*, 445-451.doi:10.1016/j.learninstruc.2004.06.014

Wade, R. C. (1994). Conceptual change in elementary social studies: A case study of fourth graders' understanding of human rights. *Theory & Research in Social Education, 22*(1), 74-95.

Wallace, C. S., & Kang, N. (2004). An investigation of experienced secondary science teachers' beliefs about inquiry: An examination of competing belief sets. *Journal of Research in Science Teaching, 41*(9), 936-960. doi:10.1002/tea.20032

Wolf, S. J., & Fraser, B. J. (2008). Learning environment, attitudes and achievement among middle-school science students using inquiry-based laboratory activities. *Research in Science Education, 38*(3), 321-341.

Yin, R. K. (2009). *Case study research: Design and methods* (4th ed.). Thousand Oaks, CA: SAGE Publications.